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PROCEEDINGS
of the
Indiana Academy *of* Science

Founded December 29, 1885

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Volume 58

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E. ST. CLAIR GANTZ, EDITOR

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Spring Meeting
THE SHADES
May 14 and 15, 1948

Sixty-Fourth Annual Meeting
INDIANA UNIVERSITY
October 28, 29, and 30, 1948

Copies of the Proceedings may be purchased through the State Library, Indianapolis, Indiana, at $3.00 per volume. All items sent in exchange for the Proceedings and all communications to officers of the Academy, when their names and addresses are not known, should also be sent to the State Library.

Reprints of certain parts of recent volumes of the Proceedings are available for distribution as follows: copies of the constitution and by-laws (Vol. 44), and complete membership list (Vol. 56), may be secured by members elected subsequent to the publication of those volumes; copies of the codified list of duties of officers (Vol. 48) may be secured by officers, divisional chairmen, and chairmen of committees; and copies of the necrology can be supplied to relatives and friends of the deceased members. Inquiries concerning these reprints should be addressed to the Secretary of the Academy, Dr. O. B. Christy, Ball State Teachers College, Muncie, Indiana.

Reprints of technical papers in recent volumes can often be secured from the authors. They cannot be supplied by the State Library nor by the officers of the Academy.

TABLE OF CONTENTS

Officers and Committees for 1948 . . . 5
Minutes of the Spring Meeting . 7
Minutes of the Executive Committee . 9
Minutes of the General Session 15
Junior Academy of Science . . 17
New Members, 1948 . 22
Necrology . 27
Presidential Address—WINONA H. WELCH . 31

Anthropology

Abstracts of papers not published in full 47
DON W. DRAGOO—Casual observations on Angel Mounds skeletal material 50
VERNON HELMAN—Archeological manifestations of Owen County, Indiana . 53

Bacteriology

Abstracts of papers not published in full 55
HAROLD D. JAMES and JOHN A. McCLAIN—Influence of incubation temperatures on the demonstrable amount of PR8, Lee-B and FM-1 strains of influenza virus in the chorio-allantoic fluid of chick embryos 57
MARY JANE KINGKADE, DOROTHEA E. HUFF, and OTTO K. BEHRENS—The use of lysozyme in studies with a bacterial virus 63

Botany

Abstracts of papers not published in full 69
DANIEL DENUYL—Establishment and Growth of seedling reproduction of sugar maple (acer Saccharophorum) 73
K. A. WAGNER—Notes on Indiana liverworts—I . . 76
K. A. WAGNER—Notes on Indiana Liverworts—II Porella in Indiana 78
JOHN O. COTTINGHAM—Higher fungi of Marion County, Indiana 81
EMORY G. SIMMONS—Studies in the stromatic sphaeriales of Indiana—II 82
Indiana plant distribution records, IX, 1948 . 92

Chemistry

Abstracts of papers not published in full 97
D. W. PEARCE, R. E. BURNS, and E. ST.CLAIR GANTZ—Studies of lithium hydride . 99
ED. F. DEGERING—The validity of the Emil Fischer concept . 107
E. CAMPAIGNE and WALTER M. BUDDE—The structure of the stereoisomeric trithianes . 111
KENNETH N. CAMPBELL, CHARLES J. O'BOYLE and BARBARA K. CAMPBELL—The relative ease of esterification of amino alcohols 120
E. ST.CLAIR GANTZ and ETHYL SHANNON FORLAW—The relative stability of some nickel (II) complexes 125
E. CAMPAIGNE and R. BOUCHER—The preparation of some dialkylamino-alkyl esters of phenoxyacetic acids 128
W. P. FISHEL and JOHN C. HAYES—The distribution of carbon between the zirconium and ferrite phases 132
GLENN A. JACKSON—The chemistry of controlled mutations 137
JOHN W. SCHICK with ED. F. DEGERING—Certain condensations of polyamines and polyfunctional compounds . . 140
HOWARD BURKETT—A rapid method for the estimation of alcohols . 142
D. J. COOK, R. W. SEARS and DARREL DOCK—Oxidations with selenium dioxide . . 145
E. CAMPAIGNE and PHILIP R. FERGUSON—Some p-nitro- and p-aminobenzoates of sulfur-containing alcohols 148

Entomology

Abstracts of papers not published in full . . . 151
C. Edw. Marshall—Oriental fruit moth control by spraying 153
M. Curtis Wilson—The introduction of exotic species of European corn borer parasites in Indiana . . 157
W. P. Allyn—A simple larvacide for ornamental pools and spawning ponds . . . 160

Geology and Geography

Abstracts of papers not published in full . 161
Preston McGrain—Geological features of the proposed Cagle's mill flood control reservoir . 163
Preston McGrain—Ground water resources of Henry County, Indiana 173
Grant T. Wickwire—Underground water and glacial geology of Scottsburg, Indiana and vicinity . 188
Ronald L. Ives—Rainfall variability . 196
Otis P. Starkey—Optimum Indiana weather elsewhere . 206
G. David Koch—Soil conservation in action 208
Robert Rudd—A study of the cucumber industry at Terre Haute, Indiana . 214
Thomas Frank Barton—Notes on the size, distribution, and growth of Indiana cities 222
James Lee Guernsey—Some geographical factors affecting the industrial expansion of Columbus, Indiana 225
R. K. Cassell—The electric light and power industry of Indiana 232
Clyde A. Malott—Hudelson cavern, a stormwater route of underground Lost river, Orange County, Indiana 236
Charles L. Bieber—Structural trends of the southern flanks of the Wisconsin arch . 244
Stephen S. Visher—Indiana's geographic regions 246

History of Science

Abstracts of papers not published in full 250
R. R. Ramsey—Early physics in Indiana (to 1900) . 253
H. H. Michaud—A brief history of the conservation of natural resources in Indiana . 257
C. A. Behrens—Historical landmarks of chemotherapy . . . 263
R. E. Girton—Early studies on protoplasm . 268
Stephen S. Visher—Starred scientists born or trained in Indiana 274

Mathematics

Physics

Abstracts of papers not published in full 288

Psychology

Abstracts of papers not published in full . . 290

Zoology

Abstracts of papers not published in full 294
Index 295

OFFICERS AND COMMITTEES FOR 1948

OFFICERS

President, Winona H. Welch, DePauw University
Vice-President, Mason E. Hufford, Indiana University
Secretary, O. B. Christy, Ball State Teachers College
Assistant Secretary, Donald E. Miller, Ball State Teachers College
Treasurer, W. F. Morgan, Indiana Central College
Editor, P. D. Edwards, Ball State Teachers College
Press Secretary, William A. Daily, Butler University

DIVISIONAL CHAIRMEN

Anthropology, Arthur B. Carr, Indianapolis
Bacteriology, M. S. A. Campbell, Indianapolis
Botany, H. J. Brodie, Indiana University
Chemistry, E. St. C. Gantz, Purdue University
Entomology, W. P. Allyn, Indiana State Teachers College
Geology and Geography, Floy Hurlbut, Ball State Teachers College
History of Science, S. S. Visher, Indiana University
Mathematics, L. H. Whitcraft, Ball State Teachers College
Physics, J. C. Hendricks, Franklin
Psychology, D. G. Ellson, Indiana University
Zoology, J. W. Baechle, St. Joseph's College

EXECUTIVE COMMITTEE

(Past Presidents, Divisional Chairmen, and Chairmen
of Standing Committees)

W. P. Allyn, J. W. Baechle, C. A. Behrens, H. J. Brodie, M. S. A. Campbell, A. B. Carr, O. B. Christy, W. A. Cogshall, E. R. Cumings, W. A. Daily, J. J. Davis, C. C. Deam, E. F. Degering, W. E. Edington, P. D. Edwards, D. G. Ellson, H. E. Endres, R. C. Friesner, E. St. C. Gantz, W. G. Gingery, J. C. Hendricks, M. E. Hufford, Floy Hurlbut, Theodor Just, Eli Lilly, J. F. Mackell, E. G. Mahin, C. A. Malott, M. S. Markle, K. S. Means, M. G. Mellon, H. H. Michaud, D. E. Miller, W. P. Morgan, Naomi Mullendore, F. Payne, R. R. Ramsey, W. E. Ricker, J. W. Switzer, S. S. Visher, F. B. Wade, F. N. Wallace, Paul Weatherwax, Winona H. Welch, L. H. Whitcraft, J. S. Wright, T. G. Yuncker.

BUDGET COMMITTEE

(President, Secretary, Treasurer, Editor, and Chairmen of Committees
on Fifty-Year Index, Junior Academy, Library, Program
and Relation of Academy to State)

Winona H. Welch, DePauw University: O. B. Christy, P. D. Edwards, R. C. Friesner, W. G. Gingery, H. H. Michaud, W. P. Morgan, F. N. Wallace, Paul Weatherwax.

COMMITTEES

(Elected by the Academy)

Trustees of Academy Foundation (Term 4 years): Chairman, J. S. Wright, Eli Lilly and Co., Indianapolis (term ex. 1952); F. B. Wade (term ex. 1951).

Bonding of Trustees (elected annually): Chairman, R. C. Friesner, Butler University; Scott McCoy.

Research Grants (term 5 years); Chairman, T. G. Yuncker. DePauw University, (term ex. 1949); E. G. Mahin (1952), H. H. Remmers (1950), Paul Weatherwax (1951), J. S. Wright (1948), Winona H. Welch and O. B. Christy (ex officio).

STANDING COMMITTEES

(Appointed by the President, Chairmen named first)

Auditing: K. S. Means, Butler University; E. S. Elliott

Biological Survey: W. E. Ricker, Indiana University; W. P. Allyn, W. B. Barnes, H. J. Brodie, L. C. Cole, Fay K. Daily, H. O. Deay, R. C. Friesner, H. H. Michaud, H. H. Vogel, Winona H. Welch.

Fifty-Year Index: R. C. Friesner, Butler University, Nellie M. Coats, W. P. Morgan, F. N. Wallace, Paul Weatherwax.

Invitations: Naomi Mullendore, Franklin College; A. R. Bechtel, T. P. Irving, C. L. Porter, B. H. Smith, O. H. Smith.

Junior Academy: H. H. Michaud, Purdue University; N. E. Adams, W. P. Allyn, F. R. Elliott, E. Kintner, M. S. Markle, R. Earl Martin, A. Strickler, F. B. Wade, P. L. Whitaker.

Library: W. G. Gingery, Washington H. S., Indianapolis; Nellie M. Coats, R. C. Friesner.

Membership: J. E. Switzer, Indiana University; M. H. Ahrendt, Juna L. Beal, E. Byrne, Jr., M. Chanin, J. J. Davis, S. R. Esten, G. F. Hennion, L. B. Howell, J. L. Hyatt, Alma Long, J. A. Marling, A. H. Meyer, Bessie Noyes, A. E. Reynolds, J. E. Seybert, W. Shepherdson.

Necrologist: W. E. Edington, DePauw University.

Nominations: (Announced at Executive Committee Meeting in October.)

Program: Paul Weatherwax, Indiana University; W. B. Adams, W. E. Breneman, Charles Hire, F. C. Mathers, L. S. McClung, S. S. Visher.

Publication of Proceedings: P. D. Edwards, Ball State Teachers College; R. C. Corley, Paul Weatherwax.

Relation of Academy to State: F. N. Wallace, State Dept. of Conservation; E. Y. Guernsey, H. J. Reed, J. S. Wright.

Representative on Council of A.A.A.S.: E. F. Degering, Purdue University.

Resolutions: J. F. Mackell, Indiana State Teachers College, F. B. Wade, J. S. Wright.

MINUTES OF THE SPRING MEETING

THE SHADES STATE PARK

May 14, 15, 1948

President Welch called the Executive Committee meeting to order at 4:40 p.m., Friday, May 14, in the pavilion, with 25 members present.

The officers and committees reported as follows:

Treasurer. W. P. Morgan reported as of January 1, 1947, receipts, $5,247.65, with disbursements $2,917.89, leaving a balance of $2,329.76. This balance includes $1,000 in gifts for completion of the Fifty-year Index.

Editor. P. D. Edwards made the following report:

Bill for reprints of articles in Volume 56 amounting to $746.25 was received March 22, checked, approved, and forwarded to the President for her approval and payment by the Treasurer. Of this amount $592.34 will be recovered from the authors.

Part of the copy and requisition for printing and engraving of Volume 57 was taken to the bureau of printing December 29. To date, May 14, it has not been possible to secure the necessary purchase orders since the balance to the account of the Academy is less than the estimated cost of Volume 57.

Relations of Academy to State. Frank Wallace reported that there was a possibility of receiving funds from the Governor's Emergency Fund, to meet the deficiencies of the 1947 proceedings.

Fifty-year Index. R. C. Friesner reported that 70 per cent of the material was ready for publication.

Library. Walter Gingery reported that forty new serial publications have been listed since October, 1947. These included several foreign publications.

Mr. Wallace reported that there was a possibility of receiving a special room to house the Academy Library, in the State Library, when several rooms would be vacated within the next few years.

Membership. J. E. Switzer submitted 31 applications for membership. These were duly elected.

Program. Paul Weatherwax explained the trips which had been planned over the park area the next day.

Flower Committee. Dr. Friesner recommended that the Academy take steps to change the State Flower from the Zinnia, to the Wild Aster. (Aster novae-angliae) The motion was made that the committee proceed to try to obtain legislative action to make this change in the State Flower.

New Business. Dr. P. D. Edwards presented the matter of raising annual dues for membership. He pointed out that it would be necessary to change the constitution, then moved that the President appoint a committee to study the problem and present the matter in writing at the October meeting.

Stephen S. Visher presented the matter of handling reprints, and moved that the authors pay for all reprints received. Dr. Edwards seconded the motion which was carried.

A. W. Lefler, of Purdue, presented a plan, worked out by Lark-Horovitz, in which the Academy would sponsor a Science Speakers Bureau. The plan was to get the problems of Science closer to the people of Indiana by obtaining outstanding speakers for public occasions. Dr. Friesner moved and Dr. Edwards seconded the motion that such a committee be appointed by the President for study and recommendations made at the October meeting.

Mr. Howard Michaud presented plans for selecting Indiana Science talent from High School seniors and these would be eligible for scholarships in State Colleges or Universities where Science Fellowships would be offered.

The meeting adjourned at 5.45 p.m. Following the dinner, interesting pictures were shown and talks given concerning the Shades by Frank Wallace, and Fabian J. Frisz, manager of the Inn. 107 members attended the dinner.

MINUTES OF THE EXECUTIVE COMMITTEE

BLOOMINGTON, OCTOBER 28, 1948

The Executive Committee was called to order by President Welch in Room E of the Memorial Union Building of Indiana University, at 7:30 P.M. The minutes of the Spring Meeting, held at the Shades State Park, were read and approved. The reports of officers and committee representatives were presented and accepted as follows:

Academy Trustee. John S. Wright, chairman of the Trustees of the Foundation Fund, reported as follows for the year 1947-48.

Balance from previous year	$ 176 34
Receipts	209 55
Total	$ 385.89
Expenditures	
Union Trust Co. Fee	10.48
Photostat copy of resolutions	.40
Cash Balance as of October 28, 1948	$ 375.01

Assets in the Fund as of September 30, 1948

Five $1,000 U. S. Savings Bonds Series "D"—Cost	$ 3,750.00
$6,900 U. S. Treasury Bonds Series "G"—Cost	6,900.00
Six Shares Standard Oil of Indiana Common Stock Par	150 00
Total at Par or Cost	$10,800 00

Treasurer. W. P. Morgan presented a tentative financial report for the period from January 1, 1948 to September 1, 1948. His final report, approved by the Auditing Committee at the end of the year follows:

Receipts

Balance on hand January 1, 1948	$2,329.76	
Dues and initiation fees	1,205.00	
Refund for research from A.A.A.S.	150.00	
Designated gift	200 00	
Author's reprints Vol. No. 56	441.86	
Author's reprints Vol. No. 57	116.56	
Publications sold	3.00	
		$4,446.18

Disbursements

1—Program Committee	$ 206.08
2—Editor Vol. No. 57	200 00
3—Expenses of Secretary	67.91
4—Expenses of Treasurer	94.50
5—Mailing Proceedings	84.00
6—Stationery	38.11
7—Publications for Library	49.58

8—E. J. Hecker (printing for Index)	12.30		
9—Bookwalter Co. (Index)	770.15		
10—Jr. Academy expenses	17.73		
11—Author's Reprints Vol. No. 57	670.40		
12—Author award 1948 C. A. Malott	25.00		
13—Author award 1948 Ed. F. Degering	25.00		
14—C. P. Hickman research grant	75.00		
15—W. E. Thrun research grant	18.75		
16—C P. Hickman research grant	37.50		
17—Expenses to five officers as directed by action of 1947 Executive Com.	100.00		
19—Returned checks	4.00		
		$2,496.01	
*Balance on hand		1,950.17	
			$4,446.18

* Balance includes $700.00 designated for the preparation for publication of the "Indiana Men of Science"

(Signed) W. P. MORGAN, *Treasurer*
(Signed) KARL S. MEANS,
S. E. ELLIOTT, *Auditors*

Auditing Committee. Dr. Means was not present, but Dr. Wright and Dr. Morgan reported the accounts of the Academy Trustees and of the Treasurer to be in good order.

Bonding Committee. Dr. Friesner reported that the Academy is bonded in advance for two years.

Editor and Publication of Proceedings. Dr. Edwards reported that the publication of Vol. 57 has been delayed. It is hoped that it can be published yet in 1948.

Research Grant. Dr. Yuncker reported five grants for the year 1948, totaling $400. These grants were made to J. E. Potzger, $50; A. E. Reynolds, $75; W. E. Thrun, $75; Robert Drummond, $50; and C. P. Hickman, $150.

Biological Survey. W. E. Ricker reported a continuation of the activities of the committee.

Fifty-Year Index. Ray C. Friesner reported that the index has been printed and that copies are being mailed to members upon receipt of their requests. The total cost of 2000 copies of the publication was $3,977.95.

Library Committee. Walter Gingry reported that a number of serial titles, new to the library, have been added during the year—43 in all. He also reported an increased use of the library.

Press Secretary. W. A. Daily reported the usual press releases and printed announcements were sent to all the colleges and universities in the state. Photographs of all but two past presidents of the Academy have been secured for the files.

Membership. J. C. Switzer presented a tentative report.

Junior Academy of Science. Howard H. Michaud reported an increased interest during the year. Twenty-five clubs representing 20 different schools are active.

The program for the 1948 Meeting promises to be unusually good, with 12 students on the program.

Special arrangements have been made to provide overnight accommodations for Friday night at McCormick's Creek State Park, for club members who are attending the meeting Saturday.

The outstanding achievement for the year was the Indiana Science Talent Search conducted in cooperation with the science clubs of America Nineteen of the 21 state winners are now attending college; majoring in science, medicine, or engineering.

Relation of Academy to State. Frank Wallace reported the State is paying $2,500 toward the publication of the Index. The State is also cooperating in the publication of Vol. 57.

Mr. Wallace and Dr. Edwards recommended that we ask the Budget Committee for $3,500 for each of the next two years, toward the publication of the Proceedings There was general agreement on this amount.

Relation of Academy to A.A.A.S. E. F. Degering reported that he represented the Academy at the Council meeting at Washington, D. C., September 13. He reported an excellent meeting.

Relation of Academy to State Academies of Science Conference. Dr. Degering reported that an interesting meeting was held September 17 in Washington, D. C.

Nomination Committee. Dr. Welch announced the members of the committee to be R. R. Ramsey, C. A. Behrens, and T G. Yuncker. They recommended for election as Fellows the following: Nellie M Coats, State Library; Clyde G. Culbertson, I. U. Medical Center B.Z.; D. E. Miller, Ball State Teachers College, Bo.Z

Old Business. Will E. Edington reported that progress is being made in securing biographical data on men who were prominent in science in Indiana before 1900. It may take several years to complete the work, in order to have completeness and accuracy.

Dr. Friesner reported for the State Flower Committee. The recommended change from Zinnia to Aster *(novae-angliae)* will be presented to the legislature

Dr. Degering reported for the "Speaker Bureau Committee." The Committee feels that it would take about $1,500 to initiate the program, and perhaps $500 per year to keep it going thereafter. A motion was passed that a committee of 3 to 5 members be appointed to investigate the problems further.

Committee on Editorial Problems. Dr. Edwards presented a statement of the condition of finances as it relates to the publication of the *Proceedings.* The following suggestions were made by the committee.

1 As soon as possible after the completion of the printing of Vol 57, the bill should be presented and an effort made to have the state legislature grant a deficiency bill to pay the deficit and restore us to a current basis.

2. Plan to hold costs of future volumes to the amount of the appropriations *or* pay the excess from Academy funds.

3. Support a request to the legislature to change the 1947 law relating to purchases so that printing may be ordered if the estimated cost does not exceed the amount which will be in the account when the printing is completed.

Dr. Edwards reported for the Committee on Dues. The committee proposed the following amendments:

Amendments to Constitution

1. Article II. Section 2 Third sentence changed to read New members shall pay an admission fee ot $1 and the annual dues for one year.

2. Article II. Section 4. Paragraph 3. Changed to read: Each applicant club, upon meeting Academy affiliation requirements, payment of an entry fee of $1 and an affiliation fee equal to the annual dues of annual members, and upon recommendation of the committee in charge, shall receive for its files a certification of membership signed by the President, Secretary, and Treasurer of the Academy. Such affiliation shall continue upon payment of annual affiliation fee so long as the club continues to meet requirements of affiliation. Each affiliated club will receive one copy of the Proceedings of the Indiana Academy of Science.

Amendment to By-Laws

1. Article V. Section 2. (New section)

The annual dues shall be determined by the Executive Committee.

A motion was passed that the Executive Committee recommend that these amendments be presented at the business meeting Friday.

New Business. Mr. Wright presented the following resolutions, which were approved:

RESOLUTION AUTHORIZING THE TRUSTEES OF THE RESEARCH ENDOWMENT FUND OF THE INDIANA ACADEMY OF SCIENCE TO CONFORM TO THE PRESENT INDIANA LAW REGARDING INVESTMENT TRUST FUNDS

WHEREAS, the rules governing the investment of the Research Endowment Funds were written in 1919 and were the same as prescribed by the Indiana law of that time for the legal reserves of life insurance companies; and

WHEREAS, the present law is less strict, nevertheless safeguards the principal of trust funds; therefore be it

RESOLVED: that the first three lines of the section on "Investments" now reading—

> "Investments—
>
> The trustees shall keep all research endowment funds invested in standard securities, such as are prescribed by law in Indiana for the investment of the legal reserve of life insurance companies."

be changed to read as follows:

> "The trustees shall keep all endowment funds invested in standard securities such as are permitted by law in Indiana for the investment of TRUST FUNDS.

John S. Wright presented the following resolutions regarding the Research Endowment Fund:

WHEREAS, the rules and regulations governing the management of the Research Endowment Fund have not been reprinted since their original publication in the Academy Proceedings for 1919; and

WHEREAS, it is the duty of the Research Committee to cooperate with the trustees of the Fund and the Executive Committee in giving suitable publicity to the Fund and to invite contributions; therefore be it

RESOLVED: that the trustees and Research Committee be authorized to have reprinted a suitable statement of the origin and of the purposes of the Fund and of the regulations governing its administration for use in answering inquiries and in the promotion of interest in the Fund; and further be it

RESOLVED: that this statement incorporate any changes in the management of the Fund that may be authorized by resolution at this meeting.

A motion was passed that the Union Trust Company, 120 East Market Street, Indianapolis 9, Indiana, be authorized to notify the United States Treasury and others who send dividend checks to the Indiana Academy of Science Research Endowment Fund, that all checks payable to this fund should be forwarded in care of this Trust Company fiscal agent and custodian of the Fund.

Dr. Friesner presented the matter of keeping the accumulated Index up-to-date. There was general agreement that this should be done.

A motion was passed that the Executive Committee authorize the beginning of work on a ten year Index and that a committee be appointed to carry on the work.

Mr. J. S. Wright was elected to succeed himself as a trustee. He was also elected to succeed himself as a member of the Research Grant Committee for a five year term.

Dr. R. C. Friesner and Scott M. Coy were elected to continue as the committee on the bonding of trustees.

The meeting was adjourned at 10:15 p.m.

MINUTES OF THE GENERAL SESSION

BLOOMINGTON, OCTOBER 29, 1948

Dean John W. Ashton, College of Arts and Sciences, delivered the Address of Welcome. President Welch responded in behalf of the Academy.

W. E. Edington presented the necrology consisting of the following names: Emil Dietz, Milton Matter, Charles Knip and Gladys Knott.

Minutes of the Executive Committee meeting of October 28, 1948 was read by the Secretary and approved by the Academy.

Dr. Konrad Birkhaug of New York State Department of Health delivered an interesting and informational lecture on Experimental and Clinical Aspects of BCG Vaccination against tuberculosis.

The resolutions presented by J. S. Wright at the Executive meeting were read and approved.

The following members were elected to fellows:
Nellie M. Coats, State Library; Clyde G. Culbertson, Indiana University Medical Center; and Donald Miller, Ball State Teachers College.

At the annual dinner in the Alumni Hall, Union Building, J. E. Switzer presented 79 applications for membership. These were duly elected.

Dr. Ramsey, chairman of the Nominating Committee, presented the following names for officers:

President, Charles L. Porter, Purdue University; *Vice-President*, Stephen S. Visher, Indiana University. *Secretary*, O. B. Christy, Ball State Teachers College; *Treasurer*, W. P. Morgan, Indiana Central; *Editor*, P. D. Edwards, Ball State; *Press Secretary*, W. A. Daily, Butler University.*

The Divisional Chairmen elected in the sectional meetings for 1949 were announced as follows:

Anthropology—William Wallace, Indiana University; *Bacteriology*—Robert F. Ervin, Notre Dame; *Botany*—R. A. Laubengayer, Wabash College; *Chemistry*—William G. Kessel, Indiana State; *Entomology*—Edward Kintner, Manchester College; *Geology and Geography*—Preston McGrain, Ind. Flood Control & Water Comn.; *History of Science*—Paul Weatherwax, Indiana University; *Mathematics*—Paul Overman, Purdue University; *Physics*—Ancil R. Thomas, Valparaiso University; *Psychology*—E. J. Asher, Purdue University; *Zoology*—Murvel R. Garner, Earlham College.

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* Dr. Edwards declined the nomination as Editor and E. St. C. Gantz, Purdue University was elected.

Dr. P. D. Edwards reported for the awards committee as follows:

Clyde A. Malott, Indiana University to receive the E R. Cumings award in Geology and Dr. Edward Degering, Purdue University, the Wm. A Noyes award in chemistry.

James F. Mackell expressed the appreciation of the Academy to the faculty and administration of the University for the excellent manner in which the members were received.

The chairman of the Invitations Committee announced that the invitation from Wabash College for the 1949 Fall Meeting had been accepted.

Dr. James F. Mackell, Chairman of the Resolutions Committee read the following report:

"The Committee on Resolutions for the sixty-fourth annual meeting of the Indiana Academy of Science begs to submit the following·

1. The Academy wishes to express its sincere appreciation for the splendid program arranged by the program committee headed by Professor Paul Weatherwax. Mr. Prevo Whitaker of the University School is also commended for his part in arranging the program for the Junior Academy. The Academy wishes to thank Mr. Charles Weatherwax for helping to make the speakers table more attractive with the beautiful floral centerpiece.

Dr. Michaud is commended for his untiring efforts to make the Junior Academy a vital part of our Academy and for keeping our young Indiana people abreast of the times in scientific thought.

2. To the Indiana University Convention Bureau and to the Administrative officers of the University, the Academy extends its sincere thanks. Lodging rooms for our members were secured, meeting rooms were graciously provided, and we are especially grateful for the provision made for this banquet room and this excellent Academy dinner.

Indeed our hosts have made us feel very much at home on our own State University Campus."

Dr. Mason E. Hufford, Vice-President, presented President Winona H. Welch, who read a well prepared paper on, "Mosses And Their Uses."

The Sixty-fourth Annual Meeting of the Indiana Academy of Science with a general attendance of approximately 375 and a dinner attendance of 146, was adjourned.

O. B. CHRISTY, *Secretary.*

TAXONOMISTS MEETING

Dr. Naomi Mullendore, Chairman. The Plant Taxonomists held their annual meeting on Saturday morning. Professor Daniel Den Uyl was elected chairman for 1949.

INDIANA JUNIOR ACADEMY OF SCIENCE

Officers for 1948:

President: Donald Krebes, Science Club, William A. Wirt High School, Gary.

Vice President: Robert Craig, Biology Club, Lew Wallace High School, Gary.

Secretary: Jane Niles, Junior Academy of Science, Elkhart High School, Elkhart.

Members of the Council: Roy McKee, (1944-1948); Ruth Wimmer, (1945-1949); Darl Wood, (1946-1950); G. Donald Klopp, (1947-1951); Evelyn Wagoner, (1948-1952).

PROGRAM OF THE SIXTEENTH ANNUAL MEETING

October 30, 1948

Auditorium, University High School, Indiana University
Bloomington, Indiana

9:00 a. m. Exhibits, University High School Gymnasium

10:00 a.m. Morning session, Auditorium, University High School

General session, Donald Krebes, presiding.

Greetings, Prevo L. Whitaker, University High School.

Reading of minutes of the 1947 meeting, read by Robert Craig, Vice President.

Papers by club members.

1. "Experiments with a Radio Frequency Oscillator," Charles B. Ellis, Junior Academy of Science, University High School, Bloomington.
2. "Atomic Fission and Energy (illustrated)," Dick Miller and Virginia Horon, Science Club, Mishawaka.
3. "Experiments with Dry Ice," Donald Goss and Ted Logan, Phi Chem Club, Elmhurst High School, Fort Wayne.
4. "Atomic Age," Arleen Scheer, Science Club, William A. Wirt High School, Gary.

5. "Blood," Margaret Overbeck, Science Club, William A. Wirt High School, Gary.

6. "The Sand Dunes of Indiana," Tom Moon, Junior Academy of Science, Central High School, South Bend.

1:15 p.m. Afternoon session, Auditorium, Social Science Building,
Indiana University

Business session

1. "The New Castle Science Fair," Marjorie Tapscott, Biology Club, New Castle.

2. "Indian Relics," Robert Burch, Biology Club Lew Wallace High School, Gary.

3. "Birds and their Habits, (illustrated)," Judith Douthitt, National Scientific Honor Society, Bloomington High School, Bloomington.

4. "Regarding New Drugs," Mary E. Howard, 1948 Indiana State Science Talent Search Winner, Indiana University.

5. "Some Ear Marks of Glacial Period Drainage Systems," Thomas Todd, Chemistry Club, Shortridge High School, Indianapolis.

6. "The Indiana State Science Talent Search," Howard H. Michaud, State Sponsor, Purdue University.

MINUTES

The sixteenth annual meeting of the Indiana Junior Academy of Science was held Saturday October 30, 1948 in the auditorium of the University High School, Indiana University, Bloomington.

The meeting was called to order at 10:05 a.m. by the president Donald Krebes, Science Club, William A. Wirt High School, Gary, by introducing his fellow officers as follows: Vice president, Robert Craig, Biology Club, Lew Wallace High School, Gary, and Secretary, Jane Niles, Junior Academy of Science, Elkhart High School, Elkhart. The roll call of active clubs was read. An attendance of one hundred and forty five members, visitors and sponsors was registered. The minutes of the 1947 meeting were read by the vice president, Robert Craig, while Jane Niles recorded the minutes of the meeting. Mr. Prevo Whitaker, Science teacher at the University High School, welcomed the Junior Academy and expressed thanks to the Biology Club of New Castle for planning the overnight accommodations for clubs and sponsors at one of the group camps at McCormicks Creek State Park, Spencer.

The first speaker on the program, Charles B. Ellis, Junior Academy of Science, University High School, Bloomington, explained the operation of a radio frequency oscillator. He expressed enthusiasm for his hobby and stated that he hoped to continue with his studies in the future.

A team composed of Dick Miller and Virginia Horon, Science Club, Mishawaka, illustrated atomic fission and energy, using lantern slides. The structure of the atom, the relationship between plutonium and uranium and the opportunities for wise use of atomic energy were presented.

The Phi Chem Club, Elmhurst High School, Fort Wayne, represented by Donald Goss, Ted Logan and several assistants, demonstrated some practical and impractical uses of dry ice. A hammer was made from frozen mercury; kerosene was solidified to form a candle and a fire was extinguished with a dry ice and water extinguisher. All in all, it was a very colorful demonstration.

The question of atomic energy was discussed by another club member, Arleen Scheer, Science Club, William A. Wirt High School, Gary. After describing the development of and the destruction caused by the atomic bomb, her conclusion was, "The only answer to the atomic question is to live in one world, peaceably."

The president then introduced Margaret Overbeck, Science Club, William A. Wirt High School, Gary, who presented a talk on blood. She discussed blood plasma and many diseases of the blood.

The last speaker in the morning session was Tom Moon, Junior Academy of Science, Central High School, South Bend, who took us on a delightful excursion to the sand dunes of northern Indiana. He accompanied his descriptions of some of the plant and animal associations found in the dunes with beautiful kodachrome slides and closed with a cordial invitation to visit the beauty of the dunes.

The morning session was adjourned at 11:45 a. m.

The afternoon session was called to order by the chairman in room 100, Social Science Building, Indiana University, at 1:30 p. m. The first item of the business session was the election of new officers. A slate was presented by the council. The results of the election were as follows for the officers for 1949:

President: Richard Elzay, Phi Chem Club, Elmhurst High School, Fort Wayne; *Vice President:* Tom Moon, Junior Academy, Central High School, South Bend; *Secretary:* Marjorie Tapscott, Biology Club, New Castle High School, New Castle.

It was next announced that the Junior Academy Council had selected Mr. Max Forsyth, sponsor of the New Castle Biology Club, to succeed Mr. Roy McKee as the new Council member to serve from 1948 to 1953.

Robert Burch, Biology Club, Lew Wallace High School, Gary, opened the afternoon program with a talk on Indian relics. He had a fascinating collection of Indian arrow heads, bird points and small pieces of Indian pottery from many parts of the United States. He believes this to be a fine hobby as archeology is one of our important fields for investigation.

Mary E. Howard, 1948 Indiana State Science Talent Search winner and now attending Indiana University spoke on her favorite topic "New Drugs." She explained how streptomycin had been used to cure many diseases which were thought incurable. She spoke of the great progress that has been made in using vitamin E in the cure of heart disease. She is studying at Indiana University to become a laboratory technician.

The president next presented Marjorie Tapscott, Biology Club, New Castle. Marjorie gave a summary of their New Castle Science Fair held last spring. Good publicity brought visitors from many other schools. The judges for the fair included local people and representatives from several surrounding colleges. The one hundred and ten entries included some standard laboratory equipment, but home made equipment added much interest because of its originality. The Science Fair was made realistic to the group through the showing of colored motion pictures taken by the physics teacher at the New Castle High School.

Judith Douthitt, National Scientific Honor Society, Bloomington High School, Bloomington, showed slides of bird adaptations and explained how these adaptations fitted the birds in their environment.

Some Earmarks of Glacial Period Drainage Systems were then discussed by Thomas Todd, Chemistry Club, Shortridge High School, Indianapolis. An area from Anderson to Ingle was studied. Twenty foot drillings were made in bogs near Fairmont and although detailed analysis had not been made, they believe these bogs to be glacial deposits. Using colored movies taken on a field trip through these bogs last spring, the speaker described the bog flora. The group plans to continue the project next spring.

The last speaker of the meeting was Howard H. Michaud, State Sponsor, Purdue University. Professor Michaud spoke on "The National and State Science Talent Search." The National Science Talent Search selects forty winners who are given a trip to Washington, D. C. From this group two national winners each receive a four year college scholarship of $2,800 and $2,000 respectively. Eight more winners receive $400 each and $3,000 additional in scholarships is awarded at the discretion of the judges.

Last year Indiana had seventy-five entries who completed the requirements. Margaret M. Sawyer of Terre Haute received the trip plus one hundred dollars. Theodore Hopkins, Indianapolis, Joseph Harris, Evansville, Oscar Beumel Jr., Evansville, and Donald W. Zimmerman, Logansport, received honorable mention in the national competition. Of the seventy-five entries, a group of twenty-one students were chosen as the top ranking contestants in the state science talent search. These winners were offered scholarships to various colleges and universities of Indiana. Several winners received Indiana scholarships and more than half are attending colleges of the state. A number of the winners are enrolled in schools of other states on scholarship grants.

The eighth annual Science Talent Search will be conducted this year by the Westinghouse Science Talent Search in cooperation with the Science Clubs of America.

The president announced that the Council had selected Ted Logan, Elmhurst High School, Fort Wayne, as the "best boy" of the year and Marjorie Tapscott, New Castle, as the "best girl" of the Junior Academy. They will receive a year's honorary membership in the American Association for the Advancement of Science and also are invited to attend the National Junior Scientist's Assembly meeting in Washington, D. C. during the last week of December.

After expressing his thanks to those who took part in the program and to everyone who attended the president adjourned the meeting at 3:30 p. m.

EXHIBITS

Photographs: Camera Club, Sullivan High School, Sullivan, Ruth Hinkle, Sponsor.

Indian exhibit, Leaf booklets, Insect collection: Biology Club, Lew Wallace High School, Gary, Lola Lemon, Sponsor.

Physics apparatus and experiments: Phi Chem Club, Elmhurst High School, Fort Wayne, Ruth Wimmer, Sponsor.

Amphibian's of St. Joseph's County: Junior Academy of Science, Central High School, South Bend, Arthur Smith, Sponsor.

Lantern slides of special interests: National Scientific Honor Society, Bloomington High School, Bloomington, Harold Stewart, Sponsor.

Song recordings and kodachrome projections of birds: Biology Club, New Castle High School, New Castle, Max Forsyth, Sponsor.

Polished wood samples, Frog dissection, Insect collections: Junior Academy of Science, University High School, Bloomington, Prevo L. Whitaker, Sponsor.

Bulletins, Science helps for teachers: Display by the State Sponsor.

NEW MEMBERS OF THE YEAR 1948, INDIANA ACADEMY

Alexander, Mr. Paul Stephen, Indiana Central College, Indianapolis 3	Bo, Z
Ball, Miss Henrietta S., Centennial School, 6th and Bronn, Lafayette	GS
Barber, Mr. Leonard Cretes, P. O. Box 191, Washington	Bo
Bower, Miss Esther, 306 West State Street, Fortville	Bo
Brey, Mr. Wallace S., Jr., 701 E. Seminary Street, Greencastle	Ch
Britz, Mr. Edwin J., Jr., 1362 N. Ewing Street, Indianapolis 1	Ph
Brown, Miss Lucy Alace, R. 1, Vevay	Bo
Burroughs, Mr. John D., 119 Columbia Street, West Lafayette	Bo
Bushey, Dr. Clinton J., Upland	E
Carpenter, Mr. Irvin, Jr., 140 S. Salisbury, West Lafayette	Bo
Castro, Mr. Elias Adis, Anthropology Dept., Indiana University, Bloomington	A
Cedars, Miss Mary Elizabeth, 2200 N. Washington, Roosevelt School, Kokomo	G
Chandler, Mr. Leland, Friendship	Z
Christian, Mr. Howard H., 547 Prospect St., Westfield, New Jersey	Z
Clark, Miss Ann, 511 W. Columbia, Oakland City	Ba
Clark, Mr. Herbert, Jr., Route 2, Box 483, Terre Haute	Bo
Clem, Miss Gladys Marie, Eli Lilly & Co., Indianapolis 6	Ba
Clevenger, Miss Sarah Beth, 717 S. Henderson Street, Bloomington	Bo
Cockran, Mr. Glenn Ray, 1216 Hendricks St., Anderson	C
Coffing, Miss E. Charlene, Eli Lilly & Co., Indianapolis 6	Ba
Colby, Mr. Alonso Clark, Room 416, Indiana State Library Bldg., Indianapolis	G
Collier, Miss Patricia A., 1830 Clinton Street, Rockford, Illinois	Ba
Coulombre, Mr. Alfred Joseph, Wabash College, Crawfordsville	Z
Crane, Mr. William Earl, Fountaintown	C
Dean, Mr. Russell, 157 Austin Avenue, Rensselaer	Ph
Dreiling, Rev. M. M., St. Joseph's College, Collegeville	M
Easterday, Mr. Otho Dunreath, 224 N. Calvert St., Auburn	Ba, C
Easterday, Mr. Wayne G., Anderson High School, Anderson	Ba
Ebel, Miss Louise, Dept. of Biology, Valparaiso Univ., Valparaiso	Z
Eggerding, Mr. Milferd H., Geography Dept., Valparaiso Univ., Valparaiso	G
Evans, Miss Barbara Ann, 6674 North Pennsylvania, Indianapolis	Ba
Feltis, Miss Thora Jean, Route 18, Box 457, Indianapolis	C
Ferguson, Dr. James W., Butler University, Indianapolis	C
Fix, Mr. William Lloyd, P. O. Box 159, Princeton	Bo

Fuller, Prof. Forst D., Zoology Dept., DePauw Univ., Greencastle	Z
Fuller, Mr. Paul R., Psychology Dept., Indiana Univ., Bloomington	Ps
Fuller, Dr. Thomas C., Dept. of Botany, Hanover College, Hanover	Bo
Fuller, Mr. Wm. Richard, Butler University, Indianapolis	M

Gianotti, Mr. Eden J. J., Hanover College, Hanover	G
Gill, Mr. Charles W., Jr., Route 2, Wabash, c/o Loren Elliott	Z & C
Gourley, Miss Frances M., 905 Madison St., LaPorte	Bo, Z
Glaser, Mr. Robert, Psychology Dept., Indiana Univ., Bloomington	Ps
Gucker, Prof. Frank T., Jr., Chemistry Dept., Indiana Univ., Bloomington	C
Guennel, Mr. G. K., 4323 Kingsley Dr., Indianapolis	Bo
Guernsey, Mr. J. L., 18 Home Avenue, Terre Haute	G

Hallam, Mr. Kenneth Leslie, 5456 N. Capitol Ave., Indianapolis 8	Ph
Hamp, Miss Ruth Marie, Eli Lilly & Co., Indianapolis	Ba
Hare, Mr. Robert R., Jr., 3F Observatory Court, Greencastle	Ph
Hawkins, Prof. Harry Leslie, DePauw Univ., Greencastle	Ps
Hawley, Mr. Martin J., 7733 Gregier Avenue, Chicago 49, Illinois	Z
Hayes, Mr. John Clifford, Prefab. 86, Court E., W. State St., W. Lafayette	C
Hays, Mr. Robert L., 125 South Mill St., Westfield	Bo
Heckman, Rev., Norman L., St. Joseph's College, Collegeville	C
Hendrickson, Mr. Thomas M., 110½N. Lincoln St., Bloomington	G
Hickman, Mr. Cleveland P., Jr., 315 Greenwood Ave., Greencastle	Z
Hogan, Mr. Robert Eugene, 617 Second St., Columbus	G
Honeay, Mr. John S., Box 13, Whiteland	Bo
Hutchinson, Mr. Emory J., Route 1, Norman	Bo, Z
Hyer, Miss Ann, Audio-Visual Center, Indiana Univ., Bloomington	A

Jackson, Mr. Robert F., 522 Board of Trade Bldg., Indiana Flood Control Commission, Indianapolis	E
Johnson, Mr. Robert L., Dept. of Biology, Purdue University, W. Lafayette	Bo
Jump, Dr. John Austin, Biology Dept., Univ. of Notre Dame, Notre Dame	Bo

Kalter, Mr. Louis B., 717 North Ave., Dayton 6, Ohio	Z, G
Karling, Prof. John S., Biological Sciences Dept., Purdue Univ., Lafayette	B, Z
Keck, Mr. Bert Marion, Route 1, Paulding, Ohio	Bo
Kottlowski, Mr. Frank E., Dept. of Geology, Indiana Univ., Bloomington	Geo, G

Landerbaugh, Mr. E. E., Moores Hill High School, Moore Hill	Ph, C
Leininger, Mr. Richard K., Geology Div., Indiana Univ., Bloomington	C
McConnell, Mr. Rex, 2049 N. Meridian, Apt. 15, Indianapolis	C
McQueeney, Mr. Carl Ray, 4905 Matthews Ave., Indianapolis	Bo
Miller, Dr. George J., Geography Dept., Indiana Univ., Bloomington	Geo, G
Mitchell, Mr. Allen C., Physics Dept., Indiana Univ., Bloomington	Ph

Motley, Miss Jerry Anne, 1726 N. Alabama St., Indianapolis Bo, Z
Mullins, Prof. A. G., Physics Dept., Indiana Central College, Indianapolis Ph

Noyes, Mr. Bradford, 4087 N. Illinois St., Indianapolis P

Oberbacher, Mr. Marion F., Stanley Coulter Hall, Purdue Univ., Lafayette Bo
Omara, Miss Jean Anne, Mason Hall, DePauw Univ., Greencastle Z
Osmun, Prof. John V., Entomology Dept., Purdue Univ., Lafayette E

Peake, Dr. John Spencer, Chemistry Dept., Indiana Univ., Bloomington C
Phillips, Mr. Travis J., 1419 Sweetser Ave., Evansville Ph, C
Pitman, Mr. Joe A., Corydon Z

Ramsay, Mr. Robert Skinner, Anderson College, Anderson Ps
Rector, Miss Avis, 317 S. Grant, Bloomington C
Rehm, Mr. Robert A., Phi Alpha House, DePauw Univ., Greencastle Z
Reynolds, Miss Theo, Anderson College, Anderson Ps
Roney, Mr. Claud H., Anderson High School, Anderson M
Rothrock, Miss Dorothy, 1310 S. Kentucky Ave., Evansville 13 Bo
Rueve, Rev. Charles R., St. Joseph's College, Collegeville M
Ryan, Mr. Paul J., 830 Drexel Ave., Fort Wayne Z, Bo

Sanders, Mr. W. Leo, Senior High School, Anderson Ps, Bo, Z
Sayler, Mr. Max W., New Market M
Schaeffer, Prof. Harold F., Chemistry Dept., Valparaiso Univ., Valparaiso C
Scheffe, Mr. Charles Earl, 609 Middle Drive, Woodruff Place, Indianapolis Bo
Schmidt, Mr. Frederic Cowles, Chemistry Dept., Indiana Univ., Bloomington C
Schwan, Mr. T. C., Valparaiso Univ., Valparaiso C
Scofield, Mr. Robert E., Route 1, Box 105, Chesterton Bo, Z
Scott, Miss Frances I., 1048 N. Beville Ave., Indianapolis Bo
Seidel, Mr. Eugene M., Chemistry Dept., Indiana Univ., Bloomington C
Shalucha, Dr. Barbara, Botany Dept., Indiana Univ., Bloomington Bo
Shepherd, Mr. Ralph H., North Main St., Road, Bicknell Z
Sherockman, Mr. Andrew Antolcik, Evansville College, Evansville C
Sibert, Mr. George W., Wyandotte G
Sister Mary Blanche, Central Catholic High School, Clinton & Lewis Sts., Fort Wayne Ph
Sister Mary Rose Stockton, Marian College, Route 17, Box 56, Indianapolis 44 C
Starr, Dr. Donald D., Taylor Univ., Upland C
Stephens, Miss Mary Alice, 474 South Street, Franklin Ba
Stoneman, Mr. Elvyn A., Geography Dept., Indiana Univ., Bloomington Geo & G

Totten, Dr. W. Fred, Wabash College, Crawfordsville M
Tsareff, Mr. Thomas C., Jr., 1702 N. Lynhurst Drive, Indianapolis 24 C

Verplanck, Dr. William S., Psychology Dept., Indiana Univ., Bloomington	Ps
Von Wicklen, Dr. Frederick C., Indiana Central College, Indianapolis 3	C
Waldschmidt, Mr. Rudolph Charles, Psychology Dept., Valparaiso Univ., Valparaiso	Ps
Wantland, Mr. Kenneth W., 6036 Haverford Ave., Indianapolis	C
Warren, Mr. Kenneth J., Anderson High School, Anderson	Ps
Wayne, Mr. William John, R. F. D. No. 6, Bloomington	G
Williams, Dr. Eliot C., Jr., Zoology Dept., Wabash College, Crawfordsville	Z
Williams, Mr Marvin D., 328 Lawn Ave., West Lafayette	HS
Winkel, Mr. Theodore A., 607 N. East St., Madison	C
Wittig, Mr. Donald R., Butler Univ., Indianapolis	Ph
Yocom, Mr Wilbur J., Five Maples, Rosedale	Z

JUNIOR ACADEMIES

Centennial Science Club, Centennial School, 6th and Bronn Sts., Lafayette	GS
Science Club, Thomas Carr Howe High School, Indianapolis	Bo, Z, C, Ph

NECROLOGY

WILL E. EDINGTON, DePauw University

EMIL DIETZ

Rohrschach, Switzerland
February 2, 1864

Indianapolis, Indiana
September 27, 1947

Emil Dietz was a prominent Indianapolis business man who became deeply interested in science because of its philosophical implications. A prodigious reader, principally of philosophical and scientific books, he in time built up an excellent library and acquired a broad general knowledge of those fields.

Emil Dietz was born in Rohrschach, Switzerland, and was brought to Indianapolis by his parents while still a small child. He attended a German-English school until he reached the age of fourteen and then took a business course which completed his formal education. He began his business career as a bookkeeper for the Fred Dietz Company, manufacturers of wooden boxes and trucks. However, his active and practical mind asserted itself in seeking improvements in the company's manufactured products until he finally held eight patents on wooden packing box and factory truck construction, and he was finally promoted to the presidency of the company which position he held until 1910.

As one hobby he became much interested in astronomy and he possessed a four inch reflector telescope by means of which he observed and studied double stars. However, he was forced to give up his observational studies during the last ten years of his life because of blindness. He was also much interested in art and was a patron of a number of the older Indiana artists of whose work he possessed a fine collection which he had purchased when the artists were young and still struggling for recognition.

Mr. Dietz joined the Indiana Academy of Science in 1921 and while he did not present any papers he nevertheless maintained an interest in its work even in his last years. He is survived by two sons, Carl V. Dietz of Indianapolis, and Dr. Harry F. Dietz of Wilmington, Delaware, a Fellow and former Press Secretary of the Indiana Academy of Science

CHARLES TOBIAS KNIPP

Napoleon, Ohio
August 13, 1869

Denton, Texas
July 6, 1948

With the passing of Charles T. Knipp the Academy lost another one of its most prominent members and one of its few remaining ties with the early days of the Academy and Indiana science, for Charles

T. Knipp became a member of the Academy in 1894 and maintained a steady and active interest in its work through all the intervening years by attending and presenting papers which appeared frequently in the Proceedings, the last appearing in 1936.

Charles Tobias Knipp was born on a farm in Henry, County, Ohio, near the town of Napoleon, on August 13, 1869. His father was much interested in farm machinery and had a shop in which young Knipp and his brother learned to handle tools and make things, a training that influenced him throughout the rest of his life. After he had completed the work offered in the township schools and the Napoleon high school and was ready for college, his father moved to Bloomington, Indiana, so that Charles and his brother and sister might attend Indiana University. Young Knipp entered Indiana University during the last year of the presidency of David Starr Jordan.

This was a golden age for science at Indiana University and also the age of opportunity for gifted young scientists. John M. Coulter succeeded Jordan as President in 1891 at the age of 39 and, with his coming, Arthur L. Foley was made Associate Professor of Physics at the age of 24 and Robert E. Lyons was similarly promoted to Associate Professor of Chemistry at the age of 21. In 1893 Joseph Swain, at the age of 36, succeeded Coulter as President, and David M. Mottier became Associate Professor of Botany at the age of 29.

It was in this scientific atmosphere that young Knipp received his physics training, his A.B. degree in 1894, and his A.M. degree in 1896. At the beginning of his senior year he was appointed instructor in physics. He retained this instructorship while he studied at Cornell University where the Ph.D. degree was conferred upon him in 1900. He returned to Indiana University as an Assistant Professor of Physics. In 1903 he accepted a similar position at the University of Illinois, where he attained the rank of Associate Professor of Physics in 1915, and Professor of Experimental Electricity in 1917. He retired in 1937 with the rank of Professor Emeritus. During his tenure at Illinois he went to Cambridge, England, and spent the year 1910-1911 working under J. J. Thomson in the Cavendish Laboratory. He returned there again to spend the year 1926-1927 in study. Following his retirement at Illinois Dr. Knipp accepted a visiting professorship of physics at Rollins College, Winter Park, Florida, and spent the years 1942-1945 there, after which he went to live with a daughter in Denton, Texas, where he passed away on July 6, 1948.

Charles T. Knipp was an outstanding scientist, being listed in Who's Who in America and starred in American Men of Science. He was a Fellow in the American Association for the Advancement of Science and was made an Emeritus Life Member in 1943. He held memberships in the American Physical Society, the American Institute of Electrical Engineers, the Optical Society of America, and the Society for the Promotion of Engineering Education. He was active in the Illinois Academy of Science, being its vice-president in 1920-1921 and its president the following year. He was also a member of Sigma Xi, Phi Beta Kappa, Tau Beta Pi, Eta Kappa Nu, and Epsilon Chi. He was also a member of the advisory subcommittee on physics for the Century of Progress Exposition in 1933.

He was the author of a large number of monographs and scientific articles. His first paper was published in 1895 in the Proceedings of the Indiana Academy of Science, and, during the years, eighteen of his papers appeared in the Proceedings. He was a very clever designer and demonstrator of apparatus and much of his success in the class room and laboratory was due to this skill. He was also an excellent glass blower. He was the inventor of a simple alpha-ray track apparatus, efficient mercury-vapor vacuum pumps, electrodeless electric discharge apparatus, and a cold cathode rectifier, and joint inventor of an alkali-vapor detector tube for use in radio. In his later years he frequently discussed or demonstrated his apparatus before the Physics Section of the Academy.

Dr. Knipp was not only an excellent scientist but he was also a good citizen who was much interested in church and civic affairs. He served as city councilman in Urbana, seat of the University of Illinois, for many years. He loved flowers and while in Urbana had a splendid rose garden. He also had a fine collection of Indian relics.

Despite the fact that he lived outside the State for most of his life, Dr. Knipp nevertheless retained a deep interest in Indiana and Indiana science, and it is fitting that the final services for him were held at Arcadia in the State where he received the inspiration and training that made his life the success it was.

GLADYS ETHELYN KNOTT

Colfax, Indiana	New Albany, Indiana
January 20, 1884	February 26, 1947

Gladys Ethelyn Knott was one of that great group of high school science teachers who are striving to familiarize the youth of Indiana with their environment. She had become a member of the Academy of Science in 1929 and as a teacher of biological science in the Junior High School of New Albany she was instrumental in organizing the science club and affiliating it with the Junior Academy of Science in 1935 and serving as its sponsor until her death on February 26, 1947.

She was born in Colfax, Indiana, January 20, 1884, and after receiving her elementary education she continued her studies until she had secured the Master of Science degree from Purdue in 1911. She chose the career of teacher of biological science and taught in the schools of Illinois, Colorado, Florida and California, before she began her many years of service in the New Albany schools. She was an excellent and effective teacher and was highly respected and admired by her students and fellow workers.

Miss Knott was a quiet unassuming person but she possessed a charming personality. She had traveled quite extensively, especially in Mexico, Alaska and Norway, and these experiences quickened her teaching work. She was active in the American Association for University Women, the Daughters of the American Revolution, the Eastern Star and the White Shrine, and Trinity Methodist Church of New Albany. In her passing the State of Indiana loses one of its most faithful and devoted servants whose influence will continue in the lives of many of its better citizens.

MILTON MATTER

Marion, Indiana	Marion, Indiana
August 12, 1887	November 17, 1947

From its very beginning the Indiana Academy of Science has championed all movements for the conservation of the natural resources of the State, and the progress in conservation in the State during the past fifty years is largely due the efforts of such outstanding leaders in the Academy as Stanley Coulter and Richard Lieber. The need for conservation has appealed to many men whose interest in science has thereby been aroused, with the result that they have become leaders in this work. Such a man was Milton Matter who became a member of the State Conservation Commission in 1940 and served as Director of the State Department of Conservation during the years 1945 and 1946.

Milton Matter was born in Marion, Indiana, August 12, 1887, and his death occurred there on November 17, 1947. Except for relatively brief periods, most of his life was spent in Marion and he was one of that city's leading citizens. Following the completion of his public school education he entered Princeton University and was graduated in 1911. The following year he was appointed Director of John Herron Art Institute in Indianapolis. A year or two later he resigned to accept the professorship of Art History at Wells College, Aurora, New York. In 1914 he returned to Marion and became associated with the Marion State Bank of which he later became president. He was a veteran of World War I, having enlisted in the Air Corps in 1917, and later becoming a second lieutenant and commanding officer of a squadron.

Following his appointment to the State Conservation Commission in 1940 by Governor Shricker, both he and one of his sons, Milton Junior, joined the Indiana Academy of Science. Mr. Matter was also active in the Masonic Lodge and the American Legion, and he held memberships in several social and civic clubs in Marion.

While primarily not a scientist, he was nevertheless a conservationist and also interested in zoology, and to quote from an editorial that appeared in the Indianapolis Star, "Milton Matter was a versatile and all-around useful citizen and public servant."

PRESIDENTIAL ADDRESS

Mosses and Their Uses

WINONA H. WELCH, DePauw University

A botanist is frequently asked if bryophytes (mosses and liverworts) have any economic importance. The usual reply is that they are of scientific interest but have very little financial value. For some time this question and answer have been a source of interest to the writer. During the search for the uses of these plants it has been found that the term moss has been applied to many things incorrectly, that is to say, to objects which are not mosses, or has had unusual correct applications.

Due to the great looseness or flexibility of the English language, we find mosses not only in each of the divisions of the plant kingdom, Thallophyta, Bryophyta, where they are correctly classified, Pteridophyta, and Spermatophyta, but also in the animal and mineral kingdoms, and in various additional fields of knowledge.

In the thallophytes, numerous algae and lichens have been called mosses. Among examples of the former are Protococcus (Chlorophyceae), a green alga which sometimes grows on tree trunks, fence posts, telephone and telegraph poles, old buildings, etc. The layman often refers to the algae, Chlorophyceae, chiefly, which form the green scum on water as mosses. Recently the author was presented with a booklet of marine, red algae (Rhodophyceae), entitled, "California Sea Mosses," and within is this quotation, "Mosses bright, behold them, flowers of the sea."

Another group of plants in the Thallophyta to which the name moss is often applied is that of lichens, the plant bodies of which are composed of algae and fungi. Iceland moss is an erect lichen *(Cetraria islandica)*, having a foliaceous habit which suggests the appearance of a moss. Another lichen *(Cladonia rangiferina)* is often referred to as reindeer-moss, because it is almost the only source of winter food for the reindeer and caribou in high northern latitudes. The so-called old man's beard or gray moss, hanging from trees in northern swamps, is also a lichen *(Usnea)*. The terms tree moss, rock moss, and coral moss are often popularly applied to lichens in general. A lichen *(Parmelia perlata)* is used in dyeing and is popularly called canary moss. Cup moss is the name of various species of lichens, particularly of the genera Lecanora and Cladonia. *Usnea barbata* and various other pendulous tree lichens are popularly known as idle moss or beard moss.

The liverworts which compose with the mosses the division of the plant kingdom, Bryophyta, are sometimes described as the scale mosses, more particularly the Jungermanniaceae, the largest class in the Hepaticae. Indiscriminately, liverworts are often classed as mosses.

The plants in the genera Lycopodium and Selaginella in the Pteridophyta are commonly known as fir moss, clubfoot moss, or club moss. Although tree-moss is a name for various species of Lycopodium, it is particularly applicable to *L. dendroideum.* Snake moss refers to *L. clavatum.*

Passing on to the Spermatophyta one finds numerous flowering plants having in their common names the word moss. Some of the most interesting examples have been included in this discussion. In the rush family (Juncaceae), one finds the moss rush *(Juncus squarrosus).* The commonly known Spanish Moss *(Tillandsia usneoides),* sometimes called long moss, black moss, crape moss, wool crepe, barba Hispanica, New Orleans moss, and Florida moss, in southern United States, is an epiphytic member of the Pineapple family *(Bromeliaceae).* According to Aldrich, DeBlieux, and Kniffen[1], the early Louisiana settlers called this plant Barbe Espagnol or Spanish beard, and the term Spanish moss has only recently come into general use. Flowering moss *(Pyxidanthera barbulata)* is a creeping, evergreen, flowering plant of the New Jersey pine-barrens. In the Phlox family (Polemoniaceae) there are the moss pinks *(Phlox subulata)* which grow on rocky hills in central United States and are often cultivated for their beautiful flowers. The moss rose *(Rosa centifolia muscosa)* bears an abundance of glandular hairs on the peduncle and calyx, which resembles a mosslike growth and thus suggests both the common and varietal names. In Europe, the common name for the fruit of the small cranberry *(Vaccinium Oxycoccus)* is mossberry as it grows only in peat bogs, usually among the mats of Sphagnum, a moss. A catchfly *(Silene acaulis)* which grows on the highest mountains of Europe and America and within the Arctic Circle appears mosslike and bears the common name of moss campion, because of its dwarf tufted moss-like habit. Moss-locust is the common name for the hispid shrub, *Robinia hispida.* The fruit of the bur oak *(Quercus macrocarpa)* has a very pubescent involucre, giving rise to the common name of mossy-cup oak. Moss wood has reference to tree trunks and stumps which are frequently found in peat bogs. Moss-oak is oak-wood preserved in a black state in peat bogs.

In zoology, one recognizes the names of bryozoan, moss-animal, moss-coral, and moss-polyp, given to small animals which have a mossy appearance. The common name of one of the American marine fish in the Herring family is mossbanker or mossbunker *(Brevoortia tyrannus).* Mossback is also applied to fish. Anglers attribute this name to large and old fish, especially bass, in allusion to a growth of algae. The large mouthed black-bass *(Micropterus salmoides),* which occurs in Indiana, bears the common name of moss-bass. The moss-back turtle is probably coated with algae rather than mosses. In ornithology, there is listed the moss-cheeper of Scotland for the titlark or reed bunting *(Emberiza schoeniclus),* the moss-duck of England for the mallard, the moss owl for the short-eared owl of England and Scotland, the moss hammer for the European bittern of England, and the mosshead for the hooded merganser *(Lophodytes cucullatus)* of South Carolina. In entomology, one of the bumble-bees bears the common name of moss-carder and the scientific name, *Bombus muscorum,* the specific epithet originating from *muscus,* the Latin word for moss.

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[1] Aldrich, C. C., M W DeBlieux, and F. B. Kniffen, The Spanish Moss Industry of Louisiana. Economic Geography **19**, 347-357. (1943).

In geology there is the moss agate or Mocha stone which is a variety of agate containing brown, black, or green matter in filamentous or dendritic forms suggestive of vegetative growth, especially that of a moss. When gold occurs in dendritic forms it is called moss gold. If silver appears in filiform or dendritic shapes, it is known as moss silver. If zinc forms thin, brittle flakes when poured slowly into water, it is called granulated or mossy zinc.

In home economics, in dietetics, there are directions for preparing blanc mange. This food is made from a sea weed or red alga (Rhodophyceae), botanically known as *Chondrus crispus* and commercially recognized as Irish moss because of its abundance along the coasts of Ireland and Great Britain. (The rake used in gathering the Irish moss is known as a moss-rake.) Ceylon moss and Jaffna moss are common names for a seaweed or red alga *(Gracilaria lichenoides)* of Ceylon and the Indian archipelago, which is similar to Irish moss and is used for food in great quantities by the inhabitants of the above-mentioned places and by the Chinese. Corsican moss is an esculent alga *(Plocaria Helminthochorton).* And, perhaps not irrelavent to the field of home economics is moss-starch which is a kind of starch obtained from Iceland moss and other lichens. In the New York Times, March 28, 1937, a new item for a breakfast menu was introduced under this interesting title, "Alaska 'Sourdoughs' add moss to menus." The new breakfast dish recommended is "mossolyte" croquettes. The prospectors found while working in Yukon Territory that their dogs thrived on the moss, so tried it for their own diet. Since in the far North, moss usually refers to lichens, it may be assumed that these croquettes were not made of true moss.

History also has included in its pages these small plants in records of the marauders which infested the border country between England and Scotland. These bandits were called moss-troopers because the country which they inhabited was mossy or boggy. During the Civil War in the United States the name of mossback was applied in the southern states to one who avoided conscription by hiding himself. In political slang we also have the mossback, a title referring to a partisan with such antiquated notions and extremely conservative opinions that he is compared with a stone or an old tree covered with moss.

In literature one finds a title by Nathaniel Hawthorne of "Mosses from an Old Manse," which is a collection of short stories. The idle moss of Shakespeare's books is a pendulous lichen which grows on trees and is botanically known as *Usnea barbata.* The references to mosses in stories and poems concerning nature are too numerous to cite, but one quotation from a poem, "Little Sermon of Peace," by Willis

Boyd Allen, contains the following quotation with reference to the third Beatitude which seems so appropriate to these plants and their habitats that it has been included. (It may be assumed that the poet has reference to true mosses.)

"Humblest creatures of the wood
To your peaceful brotherhood
Sweet the promise that was given
Like the dew from heaven:
    'Blessed are the meek
    They shall inherit the earth';
Thus are the words fulfilled:
Over all the earth
Mosses find a home secure."

The proverb, "A rolling stone gathers no moss," is familiar to all. It may be assumed that this reference is to stones in a swiftly flowing stream. If this assumption is correct, the plants under consideration were probably algae as true mosses usually grow on stones not in motion. Or, if we conjecture a stone rolling down a bare and exposed slope, the plants to which reference was made may be lichens.

In Webster's dictionary one finds moss used as a transitive verb, so that it is correct to speak of mossing. Not strictly in the sense that moss collectors sometimes jokingly use it when they say that they are going mossing, but meaning to cover or to roof with moss or to overgrow with moss, as illustrated by the following quotation from Shakespeare, "An oak whose boughs were mossed with age." Also, in the dictionary is the descriptive adjective, moss-grown, with the meaning of overgrown with moss, and the noun, mossiness, which refers to the state of being mossy. In addition, a mosser is one who collects mosses or works with them, and a mossery is a place where mosses are grown.

In art, two names of colors are old moss green and moss gray. In music, there are the words so often sung, "The old oaken bucket, the moss-covered bucket that hung in the well."

Even a list of beverages includes the mosses although misnomers.

The moss-alcohol of Norway, Sweden, and Russia is made from reindeer moss and Iceland moss, both of which are lichens. Irish-moss ale which is assumed to be potent in the treatment of some diseases has for one of its important ingredients the Irish moss, an alga.

Although this list of the unusual or incorrect applications is incomplete, it seems sufficiently long to now stress the importance to mankind of liverworts and true mosses. It is evident that plants which have permeated such numerous and varied areas of thought have attracted the attention of man for many years. It seems that a group of plants as large as the Bryophyta, approximately 8,800 species in the Hepaticae and 14,000 in the Musci, may have some members of both scientific and economic value, the common opinion quite to the contrary with regard to the latter, especially. Peat mosses (Sphagnales) and true mosses

(Bryales) are the largest orders of mosses. Thus, they are the chief contributors of the items of importance to mankind.

The leaves of Sphagnum have a very peculiar structure and due to this peculiarity Sphagnum has many uses which cannot be attributed to other mosses. The thickness of the leaves consists of one layer of cells. There are two distinct kinds of cells in Sphagnum leaves. One type consists of large, colorless, empty cells open to the exterior by a pore. These empty cells make possible the absorbent and retaining qualities of this moss. The porous cells are surrounded by smaller, chlorophyll-containing cells.

Sphagnum bogs consist of layers of peat varying from a few feet deep to unknown depths. Animals and persons have been found in bogs, remarkably well preserved by the antiseptic properties of the peat. According to Dana, in peat bogs of Europe, in recent times, there have been discovered horses and knights in armor, from the days of the Wars of the Roses, in a very good state of preservation, and bodies of humans clothed in haircloth of a prehistoric period.

Peat moss (Sphagnum) is most efficient of all mosses in conserving water. Much sphagnum from swamps is of no commercial value because it is brittle and is of the single stem type. The plants which are of economic importance grow in mats, shaped like sponges, and can be cut out of bogs in masses. The top portion of the mass is of better quality than that beneath it, as it will absorb about 25 times its own weight in moisture in comparison with the moss in the next layer below which will contain 16-20 times its weight in water. A bale of dry sphagnum weighing only 20 pounds has been found to weigh approximately 500 pounds when soaked with water.

The peat which underlies the moss is excellent fuel material, and while burning, produces a pleasant odor. It is cut into blocks or slabs and dried. Some kinds are reported to burn longer than hard wood or coal. It has been estimated that 1⅘ tons of peat is equivalent to 1 ton of coal for heating purposes. Thus approximately one-half the heating power of good coal and more than two times the heat of wood. Peat is built by Sphagnum plants at the approximate rate of 1 foot in 100 years. Ground peat is pressed into small cubes a few inches square and sold for kindling material. A small quantity placed on wood and lighted will burn easily and will hold heat long enough to ignite hard wood.

Sphagnum, mixed with bone dust, is frequently employed by flower gardeners in the greenhouse as a mulch on top of the soil in the flower pots in which plants are being started for later transplanting in the garden. It shields the earth from the sun and stimulates root growth toward the surface.

Sphagnum is of considerable commercial use in florist and nursery trade where it is used for keeping living plants fresh during shipment. It is excellent packing material for the shipment of perishable articles to distant markets, such as fruits, vegetables, tubers, and bulbs, because it is relatively sterile, holds moisture for a long period, and acts as an insulator against heat and cold during shipment. Greenhouse operators and nurserymen have found wet peat moss useful in packing roots of plants for transportation and market. Live fish have been shipped long distances packed in sphagnum.

A form of granulated or pulversized peat moss, sometimes called peat-humus and consisting of 92% organic matter, is marketed in bags and is used by gardeners as a moisture retaining humus. It may be incorporated with soil or spread over the surface of soil as a mulch. This moss keeps the earth loose, prevents a hard top crust, discourages weed growth, and prevents the soil from cracking. Sphagnums are largely used in the propagation and cultivation of rare orchids, because of their efficiency in retaining moisture.

Peat moss is employed in forming a top-dressing for golf-course greens, and for providing an absorbent layer on poultry house floors in winter months. Dachnowski-Stokes[2] has included additional uses of Sphagnum peat: employment of it as a sanitary bedding for horses, cattle, and other livestock, with the accompanying advantages that it decays relatively slowly, absorbs and retains liquid manure more completely than do other kinds of litter, decreases losses in available nitrogen, prevents odors, checks insect pests in dairy barns, horse stables, poultry houses, and fur-bearing animal sheds; an absorbent in places lacking sewer systems; and in finely shredded condition, as a medium for germinating seeds, rooting cuttings, transplanting and growing evergreens and heaths, and as a mulch for protecting plants and soil against the effects of alternate freezing and thawing, and for reducing the number of weeds.

Warden[3] reports that sphagnum peat, valued at more than $1,200,000 is imported to the United States annually, for use of gardeners and poultrymen, and that wholesale, the peat moss brings $20 per ton.

By rapid and unlimited growth, dense mats of Sphagnum gradually fill in hollows, bogs, ponds, and small lakes. Vegetable débris is washed and blown in until vast beds of peat are formed. The mats also aid in the formation of soil which is capable of supporting the growth of higher types of vegetation, thus playing an important role in plant succession in bogs. Sphagnum mats are often large constituents of floating islands upon which trees will eventually grow. Peat mosses helped to build much of the muck land that produces our celery and other garden truck. Indirectly blueberries and cranberries are dependent upon the Sphagnum or peat moss bogs because blueberry and cranberry bogs are basically peat bogs.

Peat charcoal has been used for smelting iron and for working and tempering certain kinds of steel. Tests have proven Sphagnum to be an efficient insulating material, and peat dust to be a very effective deodorizer.

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[2] A. P. Dachnowski-Stokes, Moss Peat, its Uses and Distribution in the United States. U. S. Dept. Ag., Washington, D. C., Circular No. 167, pp. 1-11. 1931.

[3] Carl Warden, Waste Land Yields Treasure in Peat Moss, Center Barnstead, New Hampshire. Pop. Sci. Mon **136**, 112-114. (1940).

According to Newsweek, November 22, 1948, page 53, Russian mining engineers are compressing peat moss into briquettes and dipping these into liquid oxygen, in the preparation of an explosive which can be used like dynamite, with the advantages of being non hazardous in storage and transit, as well as less costly.

Laplanders and Icelanders have used sphagnums for cradle linings. The American Indians used it for diaper material. In cold countries these mosses have served as warm linings or stuffings for the loose deerskin boots which the reindeer drivers wear.

Some of the species with the greatest absorbing power have been found to be very satisfactory dressings for wounds, because it not only absorbs puss and drainage from wounds but also has antiseptic properties. History does not record how long Sphagnum has been used by the country people as a dressing for boils and discharging wounds. The story of the discovery of its value by a surgeon in the seventies of the nineteenth century is fully recorded by Heald in the Scientific American[4]. "A laborer in a peat moor in northern Germany was seriously wounded in the forearm. Not having surgical dressings at hand his companions applied 'first aid' in the form of 'peat moss' picked up from the ground. Surgical help could not be obtained for ten days. Meantime the dressings were not changed. When finally the surgeon undid the wound, he was astonished to find it practically healed. He communicated his findings to his fellow physicians, and further investigation showed the great superiority of Sphagnum moss as a dressing for discharging wounds. It then became a standard dressing in hospital and private practice. In the Russo-Japanese War, the Japanese physicians used it extensively as a first-aid dressing at the front, and sometimes these dressings were not removed for as much as ten days, and yet the wounds were generally found to be in much better condition than similar wounds dressed with cotton."

Porter[5] states that sphagnum pads absorb liquids much more rapidly than cotton, approximately three times as fast, in much greater amounts, cotton absorbing five to six times its weight of water and sphagnum sixteen to twenty-two times, retains the liquids much better and therefor fresh dressings being needed less frequently, distribute absorbed liquids more uniformly throughout their mass, are cooler, softer, and less irritating, and can be produced at less expense and more speedily in times of emergency.

Only species with dense foliage and closely set branches have the qualifications to give the advantages of Sphagnum such as high absorption capacity, sponge-like matting, porosity, softness, elasticity, lightness, and strong acid reaction. The porosity of the large but microscopic empty cells of the leaves enable Sphagnum to take up liquids much more rapidly and in amounts several times greater than the same amount of absorbent cotton.

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[4] G. H. Heald, Sphagnum Moss. Sci. Am. Supp. 87, 48 (1919).

[5] J. B. Porter, Sphagnum Surgical Dressings. Int. J. Surg. 30, 129-135. Figs. 1-8. (1917).

During World War I, a few species of Sphagnum were used in large quantities by the Allied Armies as a substitute for absorbent cotton in surgical dressings. Long ago the country people of Europe used Sphagnum and Sphagnum peat as sanitary bedding and in treatment of boils and discharging wounds of man and domestic animals. The Canadian Red Cross made over 200,000 moss dressings per month during the summer of 1918 and near the end of the war the British used approximately 1,000,000 moss dressings per month. The American Red Cross officially adopted Sphagnum moss as a standard dressing material in 1918, developed a monthly output of over 20,000 pads for American military hospitals, and prepared half a million Sphagnum dressings for the Italian Army. The species having the greatest efficiency in surgical dressings are *Sphagnum magellanicum*, *S. papillosum*, *S. imbricatum*, and *S. palustre*.[6] Sphagnum is recommended for hospital mattresses and sanitary appliances because of the absorbent and deodorizing properties, but it probably will not be used extensively because of the superior substances now in general use.

Large quantities of moss peat are produced in Europe at comparatively low cost and shipped over seas. Its consumption in our country is continually growing. In the United States there are three areas which are promising in supplying desirable moss peat, Maine, northern part of Wisconsin and Minnesota, and along the Pacific coast in northern Washington and Alaska. According to the Scientific American **166**: 198. 1942, "Alaska has a virtually untouched 'Klondike' in its 110 million acres of peat muskegs, if anyone can develop satisfactory and inexpensive ways of packing and transporting the peat."

Let us now consider the liverworts and the true mosses. The origin of the word, liverwort, was from the resemblance of some of the thallose plants to the lobes of the liver. The "doctrine of signatures" claims that these plants had valuable medicinal properties for treating liver ailments.

Liverworts and mosses are small plants, the former thallose or leafy in habit and the latter, leafy. The bryophytes lack true roots, stems, leaves, and vascular system found in the Pteridophyta and Spermatophyta. The majority of leaves are one cell in thickness. The Bryophyta are spore-bearing plants, producing the spores in the capsule of the sporophyte which is completely or almost entirely parasitic upon the gametophyte. Because of the dependence of the plants upon water for fertilization, and the inefficiency of most of the species for conserving moisture, they are usually found in shaded habitats of high humidity and low evaporation. Liverworts and mosses grow on soil, rocks, wood, and in water. Numerous species are epiphytic on the stems and leaves of other plants. Occasionally bryophytes are found in dry and sunny habitats.

The Bryophyta are important from a purely scientific view point as their morphology aids in tracing theories of development of the plant kingdom from the Thallophyta to the Pteridophyta.

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[6] A. P. Dachnowski-Stokes, Sphagnum Moss for Use in Surgical Dressings. Sci. Mon. **55**, 291-292. (1942)

Also of scientific interest are the collections of mosses and liverworts from various parts of the world because they have been of considerable significance in the study of plant migration and in the determination of the relationship of floras. W. C. Steere[7] has indicated that for the purpose the lack of important economic uses has been very advantageous for these studies because the bryophytes have not been taken from their native habitats as the inhabitants have moved from place to place.

People who collect and study mosses and liverworts do so for the sake of scientific contributions to knowledge rather than for financial or commercial profit.

The Hepaticae share with the Musci in the ability to form soil, prevent erosion, increase humus, and absorb moisture quickly through the chlorophyll-bearing parts. **Conocephalum conicum** at one time was thought to have some medicinal properties. Various species of the liverworts are attractive plants for terraria.

From an economic standpoint, it seems that their contributions to the formation of soil from bare rock surfaces and to the preparation of habitats favorable for the germination of the seeds of the herbs, shrubs, and trees which are to be their successors, compose the greatest value of the true mosses to mankind. Without soil to support the growth of herbaceous and woody plants, the sources of food, clothing, and shelter, directly or indirectly, would be greatly limited. The great economic importance of a moss covering on rock or soil is evident upon the observation of the growth of the seedlings of plants more highly evolved, growing in the mat of mosses, all of which leads to the eventual tree associations. Economically and in nature, mosses are more significant than liverworts, and in the Musci, it seems that the Sphagnales are of greater direct importance, and the Bryales of more general and indirect value.

During the summer of 1932, while a student in the laboratory of Dr. A. J. Grout, the common question, "Of what use are mosses?", was discussed. Since that date notes have been assembled regarding their importance. Dr. Grout's reply, published in the Scientific Month 38: 270. 1934, is aptly and characteristically stated, "We can neither eat nor wear them, but certain kinds have been used to stuff beds on which to sleep."

Certainly no one can be unaware of the esthetic value of the mosses and liverworts. A few moments spent in imagining the faces of canyons, rocky slopes, the sides of a spring, the forest floor, tree trunks or logs in a dense woods, stones along the brooks, and even the shaded roofs of old buildings, without bryophytes, quickly bring to our attention the beauty produced by these small and frequently unnoticed plants, which are available at all seasons of the year. The majority of the principle families are world-wide in distribution, and by carefully searching it is possible to find representatives in almost any locality.

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[7] W. C. Steer, The Collecting of Mosses and Liverworts. Instructions to Naturalists in the Armed Forces for Botanical Field Work, No. 3, pp. 1-13. 1944. Ann Arbor.

Bryophytes are the lowest, in an evolutionary way, of the existing terrestrial, chlorophyll-bearing plants, and are composed of tissues so delicate that those of the past ages have left few recognizable traces of their geological history. The study of bryophytes entails minute observation, but shows them to be of great scientific interest, because they present a special type of life history and in some groups give definite evidence of evolutionary trends in spite of the absence of reliable evidence from fossil remains of their geological history.

Recalling the "doctrine of signatures" which claimed that the medicinal uses of plants were indicated by their shape and structure, a decoction of the Hair-cap mosses was formerly much used to aid in the growth of hair.

Dicranum scoparium is often used by florists to form banks of green in show windows. Dr. T. C. Frye of the University of Washington has informed the author of the use of *Rhytidiadelphous triquetrus*, *R. loreus*, and *Hylocomium splendens* as a "green carpet" for the Rhododendron, rockgarden, and general floral shows in Seattle. These mosses grow on the floor of the Douglas Fir forests and are brought to the city for the floral exhibits in five-ton loads each year.

Conards[8] reports that some of the giant west coast mosses are serving as replacements for excelsior or shredded paper in packing crockery.

Schistostega pennata is an exceedingly interesting plant. It grows on soil and stone of caves, dark holes, and other habitats having very little light. This bryophyte is called the Luminous Moss because from the persistent protonema there comes a golden-green glow by reflected light on the luminous subspherical cells at the ends of the filaments. Dr. Grout states in Moss Flora of North America 2: 103. 1940, "This beautiful plant is probably the reality upon which is based the fairy tales of goblin gold."

Young moss capsules full of spores are rich in protoplasm and serve as food for mice and insects both in field and herbarium. However, mosses rarely serve as hosts to parasitic fungi or as food for animals.

In Europe during the past, in the process of sinking a shaft in rock, a moss-box has been employed. In this procedure dry moss was used for packing to aid in making tight joints. Concrete is now used instead of the moss.

One of the Christmas traditions in Switzerland is the custom in the homes of the mountainous regions of making a manger of moss and placing it at the hearth for the spirit of the Christ Child.

In Britain, according to Bagnall,[9] *Hypnum triquetrum*, because of its extreme elasticity and lightness, is used for packing brittle wares, and dyed an intense green for sale in shops for decorative purposes; *H. purum* serves anglers for a medium of scouring worms; *H. tamariscinum* is used for shipping leeches; and in northern England, *Polytrichum commune* is used for mattresses and regarded as superior to straw, is woven into door mats, and its stems are used for making brushes for dusting beds, curtains, carpets, hangings, etc.

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[8] H. S. Conard, How to know the Mosses. P. 10. 1944. Iowa.

[9] J. E. Bagnall, Handbook of Mosses. P 85. 1886. British.

The Laplanders use *Polytrichum commune* as bed and bedding. They select a patch of male plants, cut an area large enough for a bed or bolster, and separate this layer of entangled plants from the soil. This mossy cushion is said to be very soft and elastic, not to grow hard by pressure, and to be quickly restored to original elasticity by moisture if it becomes too dry and compressed. A similar portion serves as a coverlet. Linnaeus recorded that he had often used the Hair-cap moss in this way with much satisfaction, and added that the Laplanders tie this bed and coverlet in a roll, when necessary, and carry it with them from place to place. They have also used it for stuffing pillows and beds. At one time *P. commune,* being slightly astringent, was used as a medicine in Sweden. In Germany it is considered as a sudorific. This moss has been reported as serving as stuffing for cheap pillows and upholstery in the United States.

In parts of Sweden, *Fontinalis antipyretica* has been used for filling spaces between the chimneys and the walls, and thus, by excluding air, preventing fire. This custom was the basis of the specific epithet, *antipyretica,* and the erroneous idea that this moss is incombustible.

According to Campbell,[10] Spruce, when collecting plants in South America, found the bryophyte vegetation so luxuriant that when the forest was very wet and the mosses and liverworts were soaked with water, that their weight was sufficient to break off the branches of the trees upon which they were growing.

Even without practical importance, it is of interest to observe *Fontinalis biformis,* one of the aquatic mosses in Indiana, which produces two kinds of leaves of distinct appearance during the year. The flaccid, plane leaves develop in the spring and are replaced during the summer with firm, concave, and narrower blades. The former are commonly described as the vernal leaves and the latter as the aestival.

Moss has been used in the names of places of sufficient importance to be cited in encyclopedias. The following have been noted: Moss, Norway, Moss, district in West Africa, Mossvale, New South Wales, Moss, Mississippi, Moss, Tennessee, Moss Beach, California, Mossybrook, Washington, Mossyhead, Florida, Mosspoint, Mississippi, and Mossville in Arkansas, Illinois, Kentucky, and Louisiana.

Some scientists have found the mosses and liverworts to be sources of interesting and profitable experiments in photography of minute and microscopic structures for projection slides.

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[10] D. H. Campbell, An Outline of Plant Geography. P. 284. 1926. New York.

Proceeding to contributions more scientific, some bryophytes serve as plant indicators as do some of the spermatophytes. Fires of recent occurrence may be indicated by an abundant growth of Marchantia, Funaria, and Bryum. *Fissidens minutulus* and *F. incurvus exiguus* have been found to be indicators of sandstone substratum and *Grimmia apocarpa, Desmatodon Porteri,* and *Bryum argenteum* of alkaline substratum, and *Dicranum scoparium* and *Leucobryum glaucum* of one somewhat acid.

When it rains, mosses absorb water very rapidly through the thin-walled cells of their leaves, and as the atmosphere becomes dry the leaves close tightly to retain the moisture. The arrangement of leaves similar to the shingles of a roof, also aids in the retention of water. According to Grout,[11] "One of the most important economic services of mosses is due to this power to absorb and retain moisture. Forests are given credit for retaining moisture, preventing floods and keeping up a steady flow of water in streams, but a very large part of the water-conserving power of forests is due to the mosses which grow in the shade of the trees."

Bryophytes colonize bare rock, following the lichens. They also cover areas of soil made bare by erosion, fires, and landslides, and, when firmly established, hold the particles of earth until larger plants are able to establish themselves.

In beds of mountain streams the stones and soil are usually covered with mosses when the water is low. These plants accumulate soil which is washed down from above, continuing to collect a fresh layer of mud each season at the base of the stems, which in turn continue to elongate. Moss-covered stones in brooks are frequently found stopping quantities of sand and gravel which otherwise would have been carried away by the water.

Moss portonema is one of the first vegetative growths on soil made bare by man or nature. This forms an attached cover over the loose soil which prevents the water of spring floods and summer showers from washing away the soil. Bryophytes, especially the mosses, are of some degree of importance in breaking the force of rain upon the substratum and in the prevention of soil erosion. Those which are terrestrial anchor the particles of soil by means of their rhizoids.

The plants which are dominant in our vegetation receive their water supply through roots. Bryophytes absorb water through rhizoids and through their chlorophyll-bearing organs whenever they are moistened by rain or dew; especially is this true of the prostrate forms. In erect mosses with stems more or less solitary, the rhizoid absorption probably exceeds that of the leaves except when the plants are wet with dew or rain. Cushion plants such as *Leucobryum glaucum, Bartramia pomiformis,* and *Dicranum scoparium* absorb water readily through the aerial parts.

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[11] A J Grout, Mosses. Sci. Mon. 38, 270-273 1934.

Mosses are able to establish themselves and to thrive in regions unfavorable to more advanced plant bodies because of their capacity to dry up and then to revive in a fresh supply of moisture, because of their hardiness, and because of their ability to assimilate, apparently at very low temperatures, more quickly than the seed plants. One may be convinced, also, of the immense value of a moss covering in the conservation of water supply, by considering the amount of moisture retained by this mat of plants on rocky slopes and on the sides of canyons.

The bryophytes are considered as colonizers because they can gain a foothold on bare rock, soil, and wood, where more highly developed plants, as to evolutionary standards, have failed, and thus, over a period of time, prepare a suitable substratum for those higher forms of plant life.

Bare areas on moist ditch banks along roadsides occasionally are covered with a mat of the green felt-like persistent protonema of Poponatum, especially if the soil has been recently disturbed. The leafy gametophytes occur singly and scattered. The protonema not only supplies a large part of the nutrition and retains water for the plants, but also holds the soil in place, preventing errosion to a great extent.

In the stages of plant succession from a primary bare area of rock to climax vegetation, the mosses follow the first and second stages of crustose and foliose lichens, respectively, and precede the herbs which are succeeded by shrubs and trees. Each in turn has possession of a habitat, produces profound influences upon it, and makes conditions favorable for the next community by increase in humus and accumulation of soil, and by the production of a more mesophytic habitat.

Weaver and Clements[12] cite a moss xerosere consisting of *Grimmia, Polytrichum juniperinum, P. piliferum, P. commune,* and *Tortula.* These xerophytic mosses follow the lichens as soon as sufficient amounts of soil have accumulated in the minute crevices and depressions in the rock. These mosses can endure desiccation. The plants continue growth above and die below, and rapidly accumulate soil between the erect stems, thus continually adding to the substratum which was begun by the pioneer lichens. The depth of soil under a cushion-like moss has been found to be one inch or more, according to Weaver and Clements.

Ceratodon purpureus has been found by Gates[13] to be the pioneer in plant succession on a bare area of sand in Michigan and *Polytrichum juniperinum* to be second in the sere. The Hair-cap mosses, *Polytrichum piliferum* and *P. juniperinum* are frequently successful pioneers on sandy soils because they readily establish themselves by dense growths of rhizoids, and when covered by blown sand quickly produce long branched etiolated shoots.

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[12] J. E. Weaver and F. E. Clements, Ecology. P. 67. 1929. New York

[13] F. C. Gates, Moss in the Revegetation of an Area in northern Michigan. Bryologist **49,** 66-71. (1946).

In the succession of mosses on Lake Michigan dunes, Taylor[14] found the pioneer mosses to be xerophytes, such as *Ceratodon purpureus, Bryum caespiticium,* and *B. ventricosum,* in scattered tufts or cushions. She also found thick and continuous mats of mesophytic mosses. *Thuidium delicatulum, Hylocomium triquetrum,* and *Calliergon Schreberi,* frequently excluding all seed plants, as well as many species of mosses, and thus exerting a controlling influence upon plant succession. In the Chicago region, Taylor found *Bryum argenteum, Grimmia apocarpa,* and *Ceratodon purpureus* as successors to the crustose lichens in rock succession.

Glenn and Welch[15] found in studying the stages of plant succession in Monroe County, Indiana, that *Fissidens minutulus* and *F. incurvus exiguus* are pioneers on bare sandstone areas and that *Grimmia apocarpa* followed the lichens on exposed limestone.

Leach[16] reports that in England, *Polytrichum piliferum, P. juniperinum,* and *Ceratodon purpureus* are pioneers on various types of soil, including heath-land where Calluna has been burned. that *P. piliferum* and *P. alpinum* are pioneer species on certain kinds of rock detritus, that *P. piliferum* is a pioneer on noncalcareous soils, and that above altitudes of 600 meters, *P. alpinum* is the first moss to enter on rock detritus. In these higher altitudes *Rhacomitrium lanuginosum* forms a surface carpet against weather action but its rhizoids are not efficient to bind the soil and this layer is frequently destroyed, so *Polytrichum alpinum* serves as the pioneer and stabilizer.

Warming[17] gives special attention to the covering of moss because it differs from any other vegetative covering in its effect on the amount of water in the soil, the effect varying with the species. Species of Hypnum and of other genera in the Hypnaceae produce dense cushions, 5-6 centimeters in thickness, which lie loose on the soil. The felt of rhizoids and the protonemata of plants of Polytrichum and Dicranum permeate the soil and promote the formation of raw humus. In Arctic and Antarctic areas, Warming explains, the dense, soft carpet of moss merges into either the Polytrichum moss-tundra or the Sphagnum bog or tundra. Species of Polytrichum and Dicranum form dense, firm tufts, and intermingled with them are species of Hylocomium, Hypnum, and Rhacomitrium and liverworts belonging to the genus Jungermannia. It has been found that a carpet of moss does not desiccate the soil because the plants obtain little or no moisture from the soil by absorption and conduction, and at the same time the mosses prevent by their presence the drying out of the soil.

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[14] Aravilla M. Taylor, Ecological Succession of Mosses. Bot. Gaz. **69,** 449-491. (1920).

[15] Gail G. Glenn and Winona H. Welch, Ecological Relationships of the most common Mosses in a certain Vicinity near Bloomington, Indiana. Proc. Ind. Acad. Sci. **40,** 87-101 (1931).

[16] W. Leach, On the Importance of some Mosses as Pioneers on Unstable Soils. J. Ecology **19,** 98-102. (1931).

[17] Eug. Warming, Oecology of Plants pp. 76, 198 (1909). Oxford.

According to Braun-Blanquet,[18] *Rhacomitrium hypnoides* is an important constituent of the homogeneous moss and lichen tundra in Spitzbergen; in the moss seres in cold moist regions such as parts of Siberia, Lapland, Faroe Islands, and Spitzbergen, the climax vegetation is Rhacomitrium heath; and in Auvergne, France, there is a notable lateral advance of the *R. lanuginosum* association upon basalt rubble.

The true mosses not only contribute to the formation of soil and the increase of humus, but also to the building of rocklike substances such as tufa and travertine. Taylor has found *Brachythecium rivulare* to be a prominent tufa former. "The chemical substances (iron compounds) in the water penetrate the plant tissues which, as they grow old, resist decay and form a porous rocklike mass."

Emig,[19] in the study of travertine formation in the Arbuckle Mts. of Oklahoma, found two species of mosses, *Didymodon tophaceus* and *Philonotis calcare*, taking prominent part in the depositing of calcium carbonate, and *Brachythecium rivulare* in the depositing of iron ore. The deposits of soft limestone and travertine increase the height and width of waterfalls. Emig explains, "In spite of successive erosions, travertine continues to grow by aid of algae and mosses. The mosses act only indirectly in the precipitation of calcium carbonate, principally by supplying a larger absorptive and adsorptive surface for the evaporation of the calcareous water."

Cowles found *Cratoneuron filicinum* active in tufa formation at Turkey Run, Indiana.

Taylor[20] has found moss having a part in the formation of bog iron ore. "At Otis, Indiana, and New Lenox, Illinois, are numerous springs, water of which is highly impregnated with iron compounds. In the outlet of such a spring is frequently found large quantities of *Brachythecium rivulare* B. and S. As the iron compounds penetrate the moss tissue, a hard porous tufa is formed which becomes a part of the accumulation of bog iron ore about these springs."

Taylor continues regarding mosses contributing to the formation of floating islands in northern Indiana along Lake Michigan. "Floating islands, which seem to have had their origin in a surface mat, formed over the water as in the case of quaking bogs. Portions of mats have here broken loose from shore, and now form small islands floating without attachment to bottom or margin. One of the chief agents in formation of mat is *Campylium stellatum* (Schreb.) Bryhn. This species does not form a tufa but takes a large part in filling up bodies of water by growth upon the ground either submerged or emerging, and by aiding in the formation of a surface mat." "Wherever mosses appear, either floating or along the margin of ponds, they aid greatly in the conversion of depressions into land by promoting the advance of other terrestrial plants."

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[18] J. Braun-Blanquet, Plant Sociology. Translated, revised, and edited by G. D. Fuller and H. S. Conard, pp. 38, 307, 335. (1932). New York.

[19] W. H. Emig, Mosses as Rock Builders. Bryologist **21**, 25-27. (1918).

[20] Aravilla M. Taylor, Mosses as Formers of Tufa and of Floating Islands. Bryologist **22**, 38-39. (1919).

Mosses aid in the prevention of floods because of their ability to absorb water rapidly, to conserve moisture, and to lose it slowly.

On the other side of the ledger, moss is of economic importance in that there is cost in eradicating it in infertile bluberry fields on moist soil. Certain herbicides are recommended for controlling it on untillable land.[21]

On labels of some of the Fontinalis collections studied by the author, interesting comments contribute to the expense produced by these mosses. With a collection of *F. antipyretica* from Uinta River Canyon above Big Park, Utah, is the note that it is filling the pond above the old beaver dam. A collection of *F. Duriaei* from Cassia county, Idaho, in the Burley Irrigation District, is accompanied by the following data: "Submersed in canals, on hard bottoms, catches on most anything and holds silt, forming mounds in the canals. It is hard to kill and costs considerable to keep it out."

If one objects to mosses growing in the lawn, especially under or near trees, time and expense are required to eradicate them by means of chemical solutions, acid-bearing fertilizers, and proper plant foods for lawn and trees.

In conclusion, the peat mosses are of commercial value, today. From the utilitarian and dollar and cent point of view, true mosses and liverworts have only a few uses, if one defines use as that which immediately adds to man's material wealth, supplies man with nutritious food, or contributes in some way to man's comfort. But, quite to the contrary, if one regards the numerous general contributions and takes the long look both into the ages past and into the far distant future, in addition to the consideration of the present, an inestimable value may be placed on the direct and indirect economic importance of bryophytes to man. And, if one includes, also, scientific information, there is no doubt of the incorrectness of the statement, "Bryophytes are of little importance."

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[21] F. B. Chandler and I. C. Mason, Blueberry Weeds in Maine and their Control. Maine Ag. Exp. Sta. Bull. **443.** (1946). Orono, Maine.

ANTHROPOLOGY

Chairman: ARTHUR B. CARR, Indianapolis

William Wallace, Indiana University, was elected chairman for 1949.

ABSTRACTS

An Indiana Archaeological Field School, GLENN A. BLACK, Indiana University.—At the time the great prehistoric site known as the Angel Mounds Site was purchased it was recognized that it would be ideal for use as an outdoor laboratory for the teaching of correct archaeological methods. The large number of men who were available for use in exploration in the years 1939-1942 precluded the possibility of development of a Field School. In 1945, after Indiana University became interested in Indiana Archaeology, two students were accepted for training during the summer season. One student was taken in 1946 and two again in 1947. This period of experimentation proved so successful from the standpoint of the student and sponsor that steps were taken to make the school permanent and enlarged to accommodate a large group.

In 1948 facilities were ready for eleven students and these eleven spent ten weeks at fruitful field research during which time they became familiar with the actual problems which arise in the field and which cannot be covered in the class room. In 1949 facilities will be available for a still larger group and it is to be hoped that the twenty or more who will participate will be from several universities and from several geographical areas. With such representation will come a cross-fertilization of ideas which will make such a school all the more valuable in the years to come.

The Racial Affiliations of the Southern Utes. G. K. NEUMAN, Indiana University.—In his work among the Indian tribes of the "four-corners" region of the Southwest, the writer was able to take measurements and collect observations on a series of fifty-five full-blood Southern Utes. This constitutes the first successful attempt to collect anthropometric data of this tribe. The people are of small stature, rather heavily built, brachycephalic with high brain cases, and relatively wide noses. Their affiliations are with certain late tribes of the Southeast, central California, and Mexico. Plains influences are also discernible to a small degree.

Linguistics Without Meaning and Culture Without Words, C. F. VOEGELIN, Indiana University.—Linguists are aware of occasional attempts to find structure (or to state procedures for finding structures) without resorting to the usual distinctive features and meaning equivalences. That we actually resort to even this little in all the realm of meaning is only because it is heuristic to do so (it helps us find phonemes and morphemes). This is successful in the main but not entirely successful: loose ends in any operation involving meaning appear inescapable. The difficulty is one of statement, according to Preston (personal communication), who would make two restatements, one the converse of the other; in both of these it is understood that *units* are phonemes and morphemes: (1) in order to obtain semantic *units* (phonemes and morphemes), it is convenient to use semantic data; (2) in order to obtain non-semantic *units* (phonemes and morphemes), it is convenient to use non-semantic data. For strategy, we might agree with Preston, but we lack techniques to implement the strategy. Our techniques begin with arranging letters which represent the slow movements of muscles used in the production of sounds,—that is, we start with phonetics, not with semantic data, and yet in the general case of linguistic analysis, we have been influenced by consideration of meaning. Necessary or dispensable, this is the way it is actually done by linguistic analysts. That it is possible to avoid all meaning (equatable in part to the anthropologists' use of culture), has the advantage of avoiding loose ends, but to date, remains questionable on practical grounds: the operations employed when meaning is entirely abandoned might be prohibitively time consuming even if theoretically possible. It seems though that a computing machine with a "memory" would obviate these practical difficulties.

Anthropologists may state culture without bothering to give the terminology involved in the culture. When a rapid survey of a culture area or even a whole culture is assayed, terminology is apt to be regarded as dispensable; so also in some otherwise careful descriptions of material culture. This represents personal taste or judgment rather than a theoretical position. It seems fair to say that most anthropologists regard language, at least in its terminology aspect, as one of the ways of attesting cultural statements: obviously so in the case of kinship systems, social organization, and religion; implicitly so, in the case of material culture. In actual field practice, extraordinarily detailed terms are elicited on different parts of a basket or a house (and their manufacture); of plants and their gathering or cultivation (and their use); and indeed of all complex units of production and consumption.

Why many of these terms, elicited in the field, fail to find their way into the final published report of ethnographers is a not uninteresting question; but the fact that the terms are asked for at all suggests that they are regarded as culturally relevant by culturalists.

One paper considering the relationship of language and culture concluded that all linguistic meaning is referable to cultural statement, but questioned whether all aspects of culture are necessarily verbalized. The part that is, by definition, not verbalized has been called *covert culture;* so also, not all but some *themes* are derived from sources other than what the culture actualizing the theme has to say on the subject of the theme, which is then stated by the anthropologist but not talked about by the people whom the anthropologist is studying. This, culture without words, is now a definite theoretical position and has recently been treated in that part of theory concerned with ascribing value to cultures on the one hand, and on the other to patterns and configurations.

Unsolved Anthropological Problems of Costa Rica, ELIAS ADIS-CASTRO, Indiana University.—Because of extensive Spanish settlement, very little is left of the aboriginal inhabitants. The remaining Indians, perhaps 2000 of them, are found in the Talamanca and La Estrella areas of the country. Racially at least two elements seem to be represented: an earlier more gracile type and another whose affiliations are probably to South American tribes. Linguistically, there are similarly, Oto-Mangue relationships to the north and Chibchan ones to the south. Archaeologically only southern affiliations have been stressed, although others are almost certainly to be established.

Recent Anthropological Data on the Rhesus Factor, CHARLES E. CLAUSER, Indiana University.—In a recent study carried out on more than two hundred Indiana University students it was found that the large majority of Rh negative individuals represent the Iron Age Nordic physical type, and in nearly all the rest that there has been at least one near ancestor of that type. This strongly suggests that this reaction may be due to a mutation that originated comparatively recently in northwestern Europe.

Casual Observations on Angel Mounds Skeletal Material

DON W. DRAGOO, Indiana University

Since the beginning of excavations at the Angel Site in Vanderburgh-Warrick counties, Indiana, a rather large amount of skeletal material has been recovered. This material represents the former inhabitants of the most interesting and spectacular aboriginal archaeological site in the state.

During the past summer a preliminary survey was made of this material for the purpose of giving a general picture of these aboriginal inhabitants and as a basis for further and more thorough study in the future.

Skeletal material from all forms of burial disposal, except cremation, has been recovered from this Middle Mississippi site. Burials of adults and children are found throughout the village area with infant burials quite commonly found beneath the floors of houses. Burials are extended, partly flexed and fully flexed. Of special interest are the many human bones found that are not associated with burials.

During the past few years 220 complete or nearly complete burials have been removed. A large number of isolated bones have been found but these have little statistical value. This site can be expected to yield several hundred more burials in future excavations.

From the observations made, a general picture of the individual and his life can be drawn. The average male was of medium stature with rather broad shoulders and heavy musculature. The areas of muscle attachment on the bones are well developed and in some individuals the areas are extremely marked. The head is relative large and probably mesocephalic or low brachycephalic in form. Many males appeared extremely round-headed because of vertico-occipital deformation of the skull during infancy.

Females were relatively short in stature and light in build. The head form varies, but this may be due to some deformation. A large percentage of the female crania so far examined are dolichocephalic and possess a bun-shaped occiput. This is somewhat disquieting in a population that would normally be expected to possess roundheads. When brachycephalic crania occur there usually is some deformation. With the securing of many more individuals in the future the statistical picture may greatly change in favor of brachycephals. The female crania so far recovered are more heterogenous than those of males.

Of special interest is the cranial deformation found in these skeletal remains. The majority of males exhibit this condition in slight to marked degrees. Only a few females have deformed crania, and when present, it is usually only slight. In most cases the deformation is confined to the occipital and posterior parietal regions of the skull. Deformation of the male crania has made measurements of only slight value in the majority of individuals. Some males show deformation to such a degree that the entire skull is effected.

Generally the health of the population was good for those individuals who were able to survive infancy and early childhood. The life expectancy of these people was rather high for a primitive group. Males could usually expect to reach the age of fifty with some individuals reaching the extremely old age of sixty. Females did not fair so well because of the rigors of childbirth in which many of them lost their lives.

Of the 220 complete or nearly complete burials recovered, 30 of them, or 14%, were of infants and children. This percentage is indicative of the high mortality rate among infants and the lower age groups. Miscarriages and abortions were common as indicated by foetus burials.

A number of pathologies appear in this material. Arthritis seems to have been the most common affliction in the Angel Site population. Approximately 70% of the individuals observed in this survey manifested arthritic lipping of the lumbar vertebrae and arthritic changes in the sacra in slight to marked degrees. Some fusion of the lumbar vertebrae also occurs.

Lesions are quite common in the long bones and apparently represent various types of periostitis, osteomyelitis, and different forms of bone destruction. Such conditions may have been due to any one of several causes, such as trauma, pyrogenic infection, and tuberculosis. A spongy condition of the bone occurs, which may have been due to syphilis.

Another relatively common pathological condition found in the long bones is that of exostosis. The tibia exhibited this condition most frequently.

Evidences of old fractures are not uncommon, particularly in the long bones and the ribs.

Ear exostoses appear in a few individuals, although the percentage is not as high as in some primitive groups. None of the females observed possessed this condition.

Evidence of infection of the mastoid processes appears in a few individuals.

Pathological conditions in the teeth were very common and represented a number of diseases and malformations.

The teeth of young individuals are relatively good but show some wear. Dental caries of all sizes, shapes, and conditions were extremely common in older individuals. Caries occurred most frequently in premolars and molars.

Many of the teeth showed abrasions of various types. In some cases the cusps were entirely worn off and the enamel lost from the entire surface.

Impacted molars were occasionally found, the condition being most often in the lower third molar.

The ante-mortem loss of pre-molars and molars is quite frequent in the upper age groups.

Infection of the roots of canines and pre-molars was rather common. In a few individuals this condition was severe and had caused the destruction of considerable areas of the maxillary bone. Occasionally this infection invaded the maxillary sinuses.

A typical example of the dental condition in the upper age group is that of a male approximately 55 years of age. The teeth are extremely worn. First, second, and third lower right molars are missing. Second and third lower left molars are missing. First and third upper left molars are missing. First and third upper right molars are missing. Three of the remaining teeth have large caries. This individual also possessed extreme lipping of the vertebrae due to arthritis which probably was caused by this dental condition.

The skeletal material from this site presents many interesting problems and deserves complete investigation in the future. Until such studies are made no definite conclusions can be drawn.

Archaeological Manifestations of Owen County, Indiana

VERNON R. HELMEN, Indiana University

The Indiana Historical Bureau, aware that the archaeological past of the state becomes more difficult to recover and reconstruct with the passing of each year, has instituted county archaeological surveys that are conducted during the summer. The Bureau's hope is to eventually survey all areas of aboriginal occupation in the state. This season's investigations were carried on in Owen County.

The purpose of the survey was to determine the extent that projected flood control would effect sites in the county, as well as to determine the archaeology of the county as a whole. Initial work was made immeasurably easier by a preliminary survey made by Glenn A. Black (1) in 1932. Mr. Black kindly turned his unpublished notes over to the survey party, my wife and me.

Owen County, which is located approximately forty-five miles southwest of Indianapolis, is crossed diagonally from northeast to southwest by the west fork of White River. Eel river enters the north central portion of the county from the north and then bends almost due west to flow across the northwestern portion of the county almost to the Clay County line where it exits to the north. After looping around the county to the west, the Eel again enters in the southwest corner and flows due east for about one mile when it bends south and leaves Owen to enter Greene County.

We unceremoniously dubbed our survey method the "vacuum cleaner technique," for we tried to pick up all aboriginal material but the dirt on a site. This technique resulted in the collection of all flint chips, potsherds, and any boulders showing signs of artificial pecking or abrasion. During the evening, the material collected during the day was washed and examined for any interesting usage and the unworked material was discarded. We found that on ninety-five percent of the sites, amorphous flakes that exhibited very fine secondary chipping on one face and on a small portion of the edge of the flake were being picked up. On some of the sites, up to 60 percent of the total flakes collected showed this type of workmanship. A little experimentation showed us that we could duplicate these implements by taking an unworked flake and scraping on a stick with it. A few scrapes would form the implement, for the pressure put on the flake in scraping struck off flakes on one side only and formed a shallow concavity. It is evident then that these retouched flakes are only flakes that had been used once as a scraper, a few times at most, and then discarded.

The majority of the sites surveyed in the county and all of the major ones are located on rivers or close to them. The nine pottery bearing sites are all found in the valley of the White river. This is only logical for the semi-sedentary, semi-agricultural, pottery-making people who inhabited these sites would choose a location where good land was available for their corn. The bottoms of the White river have the best soil for corn in the county. Then too, the river offered easy transportation to these people who lived in this formerly heavily wooded area.

The large village sites in the southern part of the county, especially Hickam Village site, show certain relationships with Greene County material reported by Black. (2) The village is accompanied by two mound groups, one of eight small mounds, and one of four. These mounds tend to be grouped in three's a Green County trait. The mounds have been pitted in all but three instances and one mound was partially destroyed when a tree growing upon it blew over. Stone slabs in the interior of the mound are revealed in the hole caused by the fall of this tree; such slabs in mounds also occur in Greene County. The pottery from this site is the common grit-tempered, cord-marked Woodland ware. One of the large vessels found here is shown on page 250 of Lilly's "Prehistoric Antiquities of Indiana." (3) The village area was under cultivation this summer and many refuse pits were apparent, showing up as dark areas in the sandy soil on which the village was located. All of the arrowheads found at this site were of the notched or stemmed type, no triangular points occuring.

The Summit Village site in the northern portion of the county does not show this close relationship with Greene County. Here there is only an artificially modified knoll instead of a mound group, over half of the arrowheads are triangular, though of the wide-based woodland type. The pottery, while Woodland, exhibits modification in that all rim sherds recovered were maleated on the lip while the clay was still plastic. This resulted in beveling the rim in a distinctive manner not seen elsewhere in the county. This type of rim treatment is seen in Castle Creek Focus (Owasco Aspect) of New York State, as is the predominance of triangular points.

One other site, the Pectol Camp site on Rattlesnake Creek, shows interesting divergence. Here, in an area approximately 100 x 100 feet, we picked up on the surface more than twenty hand mullers and slab morters. No other site in the county produced so many of these implements, though hand mullers were quite common.

In summation, it can be said that Owen County was occupied by Woodland peoples though, as you can see, with variations from site to site. Hickam Village site and the Summit Village site need to be examined more closely to determine the extent of their divergence and their relationships to other areas.

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2. Black, Glenn A., The Archaeology of Green County, Indiana History Bulletin, Vol. X, No. 5, 1933.
3. Lilly, Eli, Prehistoric Antiquities of Indiana, Indiana Historical Society, Lakeside Press, R. R. Donnelley & Sons Company, Chicago, 1937.

BACTERIOLOGY

Chairman: M. S. A. CAMPBELL, Indiana State Board of Health

Robert P. Ervin, Notre Dame, was elected chairman for 1949.

ABSTRACTS

Comments on Aerating Liquids by Shaking

OPAL B. STARKS and H. KOFFLER, Purdue University*

Although agitating submerged cultures of certain microorganisms on shaking machines has become a popular method of supplying microorganisms with oxygen, the question of exactly how much oxygen this procedure makes available to them is still open. The following approach was used to obtain at least some preliminary answers to this question: One hundred and fifty ml of freshly boiled and rapidly cooled distilled water, sometimes containing added substances, in 500 ml Erlenmeyer flasks were agitated at 28°C on a reciprocating shaker, having a 4 inch stroke and shaking at a rate of 85 strokes per minute. At zero time and intervals thereafter the amount of oxygen dissolved was determined by the Winkler method. The rate at which oxygen diffused into distilled water during the first 30 seconds was approximately 300 ppm of O_2 per hour, and 50 ppm of O_2 per hour, when the liquid was still. The addition of glucose to give a 0.5 percent solution did not appreciably alter the rate of diffusion; the addition of gum arabic on the other hand reduced the rate of oxygen diffusion as well as the total amount of oxygen dissolved after 3 hours, probably because it increased the viscosity of the liquid. When nitrogen was bubbled from a sintered-glass aerator through a 2.5 percent solution of gum arabic, a thick foam developed, which completely covered the solution and inspite of agitation stayed intact for about an hour. As long as this foam persisted, the diffusion of oxygen was almost completely prevented. The foams that commonly form during actual shake-flask fermentations may not interfere as seriously with aeration as did the gum arabic foam in these experiments; nevertheless, to guarantee an adequate supply of oxygen considerable foaming should be avoided by the addition of suitable anti-foam agents. When "penicillin defoamer" was added to the solution of gum arabic, no foam developed and diffusion of oxygen into the solution proceeded fairly rapidly.

Some Biological Properties of Circulin, an Antibiotic from Bacillus Circulans. O. W. KAUFMANN, P. A. TETRAULT, AND H. KOFFLER, Purdue University.—*In vitro* circulin very effectively inhibited representatives

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[*] Laboratories of Bacteriology, Department of Biological Sciences.

of the following genera: *Aerobacter, Brucella, Escherichia, Klebsiella, Neisseria, Pseudomonas, Salmonella,* and *Shigella.* In general, gram-negative bacteria were more sensitive to polymyxin than to circulin; the opposite was true for gram-positive bacteria. A polymyxin-resistant strain of *Pseudomonas aeruginosa* was less resistant to circulin than it was to polymyxin. The LD_{50} for circulin, given to white mice by single intraperitoneal injections, was approximately 68 mg per kilogram. One hundred percent of the mice survived after having received daily intraperitoneal injections of 45 mg per kilogram for 10 days. Preliminary experiments indicated that circulin protected white mice against 100 minumum lethal doses of *Klebsiella pneumoniae* given intraperitoneally.

Influence of Incubation Temperatures on the Demonstrable Amount of PR8, Lee-B and FM-1 Strains of Influenza Virus in the Chorio-Allantoic Fluid of Chick Embryos

HAROLD D. JAMES, D.V.M., M.S. and JOHN A. MCCLAIN, B.S.A.

Greenfield Biological Laboratories, Eli Lilly and Company

Greenfield, Indiana

The chick-embryo in the past few years has become increasingly important as an experimental host for influenza virus as well as being used for the commercial production of influenza virus vaccine. Many investigations have been conducted to ascertain the specific roles of a number of variables which are known to be involved in the relationship between the infective agent and the host. Some of the variables which have been studied are (a) the concentration of the virus in the inoculum, (b) the length of time of incubation of the infected embryos, (c) the age of the embryos at time of inoculation, (d) the temperature of incubation of the embryos before inoculation, and (e) the temperature of incubation of the infected embryos. Relative to the studies conducted concerning the temperature of incubation of the infected embryos the investigators have used on the most part small numbers of eggs in conducting their studies. It has been our experience, from a production view point in which as many as 100,000 eggs are inoculated per week, that one is not always able to obtain the same results when using a large number of eggs as an investigator who has published data in which only a few eggs have been used, though one endeavors to conduct ones production methods in an identical manner to the experimental methods. Miller (1) has conducted some studies upon the production of A virus (PR8 strain) at various temperature levels and found maximum virus production to occur when the embryos were incubated at 35°C. Beard (2) and his group of co-workers at Duke University suggest 39°C. while Henle (3) suggests 36-37°C. for this same strain. In studies upon the production of B virus (Lee strain) at various temperature levels Beard (4) found maximal infectivity as well as greater hemagglutinative activity when the embryos were incubated at 35°C. No reference in the literature could be found concerning the optimal temperature level for the production of the A virus (strain FM-1). This particular strain was isolated in 1947 and the National Institute of Health had all producers of influenza virus vaccine to substitute this strain for the Weiss strain which had formerly been included in their mixed vaccine product. The results obtained with all three strains of the influenzal virus are described in the present paper.

Materials and Methods

Stock Inoculum.—Infectious allantoic fluid obtained by the regular passage of the particular strain through eggs for seed purposes was used. The PR8 strain contained around 250 units of CCA activity per cc. (5) The Lee strain 100 and the FM-1 strain 100.

Inoculations.—Eggs for the experiments were obtained from a commercial hatchery which also supplies us with our eggs used for production purposes and had been incubated 11 days at 37.5°C. The eggs were inoculated, into the chorio-allantoic sac, at room temperature with 0.2 ml of a suitable dilution in saline of the stock virus by means of a mechanical egg inoculating machine developed in our own laboratories and capable of inoculating 6000 eggs per hour. The openings in the shells were not sealed since we have found it is unnecessary to do so. The eggs were then incubated for 48 hours at the desired temperature range, and the humidity kept at a high level. At the end of the 48 hour incubation period the eggs were candled and all dead embryos discarded. The eggs having living embryos were then chilled for approximately 24 hours at the end of which time the allantoic fluid was aspirated and tested for CCA activity.

Measurements of Virus Activity.—Assuming that virus infectivity and chicken red blood cell agglutination (CCA) activity are the properties of the same molecule (6), the relative amounts of virus were measured indirectly by means of determinations of CCA titers. The CCA titrations were carried out according to the method of Hirst and Pickels (7), as modified by Miller and Stanley (5).

Experimental Results

Table I shows the results of three separate trials using PR8-"A" virus at incubation temperatures of 33°-35°C., 35°-37°C., and 37°-39°C. In trial 1 it will be noted that the CCA titer of the eggs incubated at 33°-35°C. and 35°-37°C. is indentical while that of the eggs incubated at 37°-39°C., is less than one-third this amount. Trial 2 shows practically the same relation existing between the various temperature levels as did trial 1. In trial 3 the eggs incubated at 35°-37°C. had a slightly higher CCA value than those incubated at 33°-35°C. It will be noted in all three trials that the eggs incubated at 37°-39°C. had a much higher death rate than those incubated at the two lower levels. It was because of the much higher death rate at 37°-39°C. that the number of eggs inoculated in trials 2 and 3 for incubation at this level was reduced in comparison to the number inoculated for incubation at 33°-35°C. and 35°-37°C. A total of 1008 eggs was used in these three trials.

TABLE I

The red blood-cell hemagglutinative and CCA activity of chorioallantoic fluid from chick embryos incubated at various temperature levels after inoculation with PR8 influenzal virus.

Incub. Temp.	Trial	Length of Incub. Hrs.	No. Eggs Inoc.	Death Rate %	CCA Value
33°-35°C	1	48	118	11.85	250
	2	48	137	22.6	125
	3	48	150	10.0	225
35°-37°C	1	48	119	15.8	250
	2	48	137	30.7	125
	3	48	150	20.0	250
37°-39°C	1	48	119	63.8	70
	2	48	50	78.0	50
	3	48	28	100.0	.

Table II shows the results of three separate trials using Lee "B" virus at incubation temperatures of 33°-35°C., 35°-37°C., and 37°-39°C. In trial 1 it will be noted that the CCA titer of the eggs incubated at 33°-35°C. and 35°-37°C. is identical while that of the eggs incubated at 37°-39°C. is practically nil. The results obtained from the 37°-39°C. incubation temperature substantiated previous tests not included in this paper and consequently no further tests were repeated at this temperature level. Trials 2 and 3 both indicate very little difference in virus activity between the two temperature levels. Comparing the death rate of the embryos at the various temperature levels there was 2.2% less deaths in the group incubated at 33°-35°C. than there was in the group incubated at 35°-37°C. The 37°-39°C. group again had a much higher death rate in comparison to the other two groups. Beard (8) suggests that the small quantity of Lee "B" virus demonstrable in the chorio-allantoic fluid of embryos incubated at 39°C. may be due to the inactivation or breaking down of the virus that is formed by exposure to adverse pH of the chorio-allantoic fluid, as the fluid descends into the acid region at 39°C. Miller (9) has found that the optimum pH range for the stability of influenza virus B is at or above pH 7.9 while that for optimum stability (9) of PR8-"A" is 6.5 to 7.0. A total of 1234 eggs was used in the study of the Lee B virus.

TABLE II

The red blood-cell hemagglutinative and CCA activity of chorio-allantoic fluid from chick embryos incubated at various temperature levels after inoculation with Lee "B" influenzal virus.

Incub. Temp.	Trial	Length of Incub. Hrs.	No. Eggs Inoc.	Death Rate %	CCA Value
33°-35°C	1	48	132	3.8	100
	2	48	204	11.2	150
	3	48	145	7.6	100
35°-37°C	1	48	273	6.0	100
	2	48	203	12.3	125
	3	48	145	11.0	100
37°-39°C	1	48	132	18.2	10
	2	Not Repeated			
	3	Not Repeated			

Table III shows the results of the trials made using the FM-1 virus. Trial 1 indicates about twice as much CCA activity in the chorio-allantoic fluid from the embryos incubated at 35°-37°C. than those incubated at 33°-35°C. and 10 times more than from the embryos incubated at 37°-39°C. Trials 2 and 3 indicate a slightly greater amount of CCA activity

TABLE III

The red blood-cell hemagglutinative and CCA activity of chorio-allantoic fluid from chick embryos incubated at various temperature levels after inoculation with FM-1-"A" influenzal virus.

Incub. Temp.	Trial	Length of Incub. Hrs.	No. Eggs Inoc.	Death Rate %	CCA Value
33°-35°C	1	48	104	24	50-75
	2	48	150	20	60
	3	48	100	16	125
35°-37°C	1	48	104	12.5	125
	2	48	150	26	80
	3	48	100	7	150
37°-39°C	1	48	104	15.3	10
	2	48	150	16	5
	3	48	100	12	50

in the chorio-allantoic fluid from the embryos incubated at 35°-37°C. than from those incubated at 33°-35°C. Only small amounts of CCA activity is indicated by trials 2 and 3 as being present in the chorio-allantoic fluid of the embryos incubated at 37°-39°C. Relative to the death rate of the embryos during the 48 hour incubation period there was approximately 5% less deaths in the 35°-37°C. range as compared to the 33°-35°C. group. There was a total of 1062 eggs used in this study of the FM-1strain.

The authors of this paper feel that mention should be made of the fact that some investigators, i. e. Salk (10), feel that conditions of cultivation of the various strains within the ddifferent laboratories may also have an effect upon many strain and line differences that are noted. If this be true, then the differences in optimal incubation temperature for the production of PR8 virus, that is mentioned by the different investigators in the beginning of this paper, can be explained. This same fact might also explain the findings of the present authors relative to the optimal temperature level of incubation for the production of PR8 and Lee virus being the same, as the seed for each strain has been carried in an identical manner in regard to the temperature of incubation since we received the original strains in 1944. Incubation of the seed has always been done in the same incubator in which our production eggs are incubated, and because of the size of this incubator room we have a temperature variation of at least ±1° at 36°C. Our present findings would seem to indicate that we would have more FM-1 virus produced if we incubated this strain at 35°-37°C. while 33°-35°C. would optimum for the production of the PR8 and Lee virus using the particular strains which we have in our laboratory.

Summary

1. Very little, if any, difference in demonstratable PR8 virus as measured by the CCA test and the hemagglutination test was noted between the chorio-allantoic fluid of eggs incubated for 48 hours at 33°-35°C. and 35°-37°C.

2. Very little difference in demonstratable Lee virus as measured by the CCA test and the hemagglutination test was noted between the chorio-allantoic fluid of eggs incubated for 48 hours at 33°-35°C. and 35°-37°C.

3. From an economic view point, because of a lower embryo death rate, the optimum temperature level of incubation would be 33°-35°C. for the particular strains of PR8 and Lee virus which we have in our laboratory.

4. The optimum temperature level of incubation for the maximum production of FM-1 virus in the present experiments was 35°-37°C.

5. The present experiments indicate that the 37°-39°C. temperature level of incubation was unsuitable for the cultivation of any one of the three strains studied.

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The Use of Lysozyme in Studies With a Bacterial Virus

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In the field of virology available evidence points toward the probability that the cells, in which multiplication occurs, provide metabolic organization required for virus synthesis, and that the virus, in some way, supplies a directive influence. Cells of *B. coli* infected with T_2 bacteriophage are incapable of normal growth and division though their metabolism continues at a high rate (1). This metabolism is now directed toward synthesis of nucleic acids and proteins which eventually become a part of the multiplying virus.

Although little information is available concerning the processes which occur in biological synthesis of nucleic acids and proteins, conditions necessary for a number of biological synthetic reactions have recently been ascertained. Since a number of these can be demonstrated in cell-free media, the hope is nurtured that virus multiplication in cell-free media may be possible. From time to time reports have been published that this has been accomplished (2). None of these claims have as yet been substantiated by other groups. It is evident, however, that the discovery of conditions permitting virus reproduction in the absence of cells would make available an important new tool for virus work. For this reason it is desirable that this possibility be reinvestigated from time to time as additional knowledge concerning viruses and concerning the biochemistry of cellular metabolism becames available.

The experiments reported in this paper gave no indication of reproduction of bacteriophage. The presentation of this work appears justified in order that undue repetition by others may be avoided, and in the hope that the considerations which led to the choice of conditions for these experiments may be suggestive for further fruitful experimentation.

A medium containing all possible cellular components appeared to offer the best opportunity for success. An attempt was made to choose conditions which would:

(a). Provide a method of cell lysis in which intracellular constituents (enzymes, proteins, etc.) would not be denatured or destroyed. For this purpose lysozyme, which presumably acts only on the cell wall, was chosen. It was consequently necessary to choose a lysozyme-sensitive organism which serves as a host for a virus. *Staphylococcus aureus* strain K_1, and P_1 bacteriophage* were chosen to fill this requirement.

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* The Staphylococcus aureus K_1 and bacteriophage P_1 were obtained from Dr. A. P. Krueger.

(b). Maintain a high concentration of constituents in order that dissociation of enzyme-coenzyme combinations would be minimized.

(c). As far as possible avoid autolysis. In many of the experiments sufficient lysozyme was added to give considerable lysis in a brief period. Phage was always added to the lysate as promptly as possible. Cooling was also used to decrease the rapidity of autolytic reactions.

During the course of the work, in personal conversation with Dr. Krueger, we learned of his experiments with the same organism, phage, and with lysozyme in which an average increase of phage of 180 percent was observed. Dr. Krueger very kindly informed us of the conditions of his experiments (3). The first four experiments in Table I are typical of a larger series which we have conducted. No significant increase of phage was observed.

In these experiments one percent of egg white was added to a bacterial culture containing 1-2 x 10^9 cells per ml. and lysis was allowed to proceed for twelve minutes. Cells which had not been lysed were removed by filtration through a super-cel pad prepared according to the method of Krueger, Scribner, and Brown(4). The cell-free filtrates were collected in a chilled flask, inoculated with phage, and held at 5^0 for thirty minutes. Phage assays were made by the plaque count method of Hershey, Kalmanson and Bronfenbrenner (5).

Experiments 5 (a) and (b) (cf. Table I) were conducted in similar manner with addition of 0.85% and 2.3% NaCl respectively to the laysates before addition of phage. Utter, Krampitz, and Werkman (6) had reported that addition of sodium chloride to lysed preparations of *Micrococcus lysodeikticus* made possible the demonstration of enzymatic activities which were not observable in salt-free lysates.

In experiment 6 pyruvate, Mg^{++}, $PO_4^{\equiv}$, sodium chloride. potassium chloride, adenosinetriphosphate, and cytochrome c were added to the lysate before addition of phage. Several workers have recently reported observations that cellular preparations maintained in media containing these substances are able to carry out a number of complex enzymatic oxidations (7).

Experiments have also been conducted varying from the above in other respects. If phage reproduction is directly associated with enzymatic manifestations of the virus or the host, such enzymatic activity probably should occur more readily at 36° than at 5°. For this reason use of the higher temperature was also investigated. In addition, in many experiments crystalline lysozyme has been used with a somewhat longer period of lysis of host cells. Removal of unlysed cells was accomplished by use of a Berkfeld filter. Experiment 1, Table II represents one of the experiments of this group illustrating variation in the time of lysis. It seemed possible that the period of cellular invasion by phage might be eliminated by use of lysates. In this event multiplication might occur in a shorter interval than that observed with intact cells. In experiment 2, the effect of varying periods of incubation of phage and lysate was studied. It will be noted that no indication of multiplication was noted at either short or longer intervals.

TABLE I. Incubation of Bacteriophage in Bacterial Lysates.

Expt. No.		Amt. Lysis 12 Min. (1/100 Egg White)		Phage Added	Phage Found After 30 Min. at 5°		Egg White in Saline
		From	To		Bacterial Filtrate	Bacterial Lysate	
1.		1.2×10^9	5.3×10^8	2.0×10^6	2.4×10^6	2.8×10^6	
2.		1.4×10^9	8.5×10^8	1.5×10^6	1.4×10^6	1.6×10^6	1.1×10^6
3.		1.2×10^9	5.0×10^8	5.3×10^5	4.2×10^5	3.9×10^5	3.9×10^5
4.		1.5×10^9	6.4×10^7	5.0×10^4	6.1×10^4	6.0×10^4	7.5×10^4
5.	(a)	1.8×10^9	6.9×10^8	1.9×10^6	1.4×10^6	1.6×10^6	1.3×10^6
	(b)				1.6×10^6	1.8×10^6	1.6×10^6
6.		1.0×10^9	9.4×10^7	9.2×10^5	5.9×10^5	5.7×10^5	6.9×10^5

TABLE II. Incubation of Bacteriophage in Bacterial Lysates

	Time Lysis	Amt. Lysis	Phage Added	Phage Found After 10 Mins. at 36°		
				Bacterial Filtrate	Bacterial Lysate	Egg White in Saline
1.	4 hrs.	8.4 x 10^{9} 7.4 x 10^{8}	4.0 x 10^{5}	7.6 x 10^{5}	2.2 x 10^{5}	3.1 x 10^{5}
	2 hrs.	8.4 x 10^{9} 2.4 x 10^{9}	4.0 x 10^{5}	4.2 x 10^{5}	2.4 x 10^{5}	
	30 min.	8.4 x 10^{9} 4.2 x 10^{9}	4.0 x 10^{5}	3.7 x 10^{5}	5.6 x 10^{5}	
2.	12 min.	1.1 x 10^{9} 3.6 x 10^{8}	1.0 x 10^{6}	(10 min.) 9.2 x 10^{5}	7.4 x 10^{5}	8.9 x 10^{5}
				(30 min.) 1.2 x 10^{6}	7.2 x 10^{5}	8.3 x 10^{5}
				(75 min.) 8.5 x 10^{5}	9.0 x 10^{5}	6.1 x 10^{5}
				(120 min.) 7.8 x 10^{5}	7.0 x 10^{5}	7.3 x 10^{5}
3.	2½ hrs.	(a. cell free) 3.0 x 10^{4}		6.0 x 10^{4}	7.0 x 10^{4}	
	2½ hrs.	(b. 2.5 cells per ml.) 3.0 x 10^{4}		5.7 x 10^{4}	1.2 x 10^{5}	
	2½ hrs.	(c. 2,500 cells per ml.) 3.0 x 10^{4}		3.0 x 10^{4}	3.1 x 10^{4}	
4.	4 hrs.	(unfiltered) 1.9 x 10^{9} 3.9 x 10^{8}	8.4 x 10^{5}	2.7 x 10^{5}	5.4 x 10^{5}	
5.	4 hrs.	2.8 x 10^{9} 1.9 x 10^{8}	2.2 x 10^{5}	a) 2.7 x 10^{5}	1.9 x 10^{5}	2.9 x 10^{5}
				b) (3 mg./ml. of ATP) 1.8 x 10^{5}	2.0 x 10^{5}	2.4 x 10^{5}

It seemed possible that rapid destruction of enzymes or other labile materials necessary for phage reproduction might account for failure to obtain phage increase. Continuing lysis of a few cells might provide a supply of such materials. In experiment 3, the three parts represent bacterial filtrates to which (a). no cells were added; (b). 2-3 cells per ml. were added; and (c). 2500 cells per ml. were added to the lysate prior to addition of phage. In experiment 4 the filtration to remove cells was omitted. No significent increase in phage was observed. Similarly addition of adenosinetriphosphate to provide a source of energy for synthetic reactions was without effect.

Thus, to date we have not been successful in demonstrating significant increase in phage in lysozyme-lysates.

Cohen (8) has recently obtained evidence consistent with the interpretation that intracellular phage formation may proceed at a constant rate starting at the time of infection and terminating with lysis of the cell. In contrast, the work of Latarjet (9) indicated that the formation of phage was not completed until just before lysis. It occurred to us that lysis of infected cultures by lysozyme during the "constant period" might provide evidence bearing on this point, for demonstration of an increase in phage would strongly indicate formation of additional phage before the usual time of lysis.

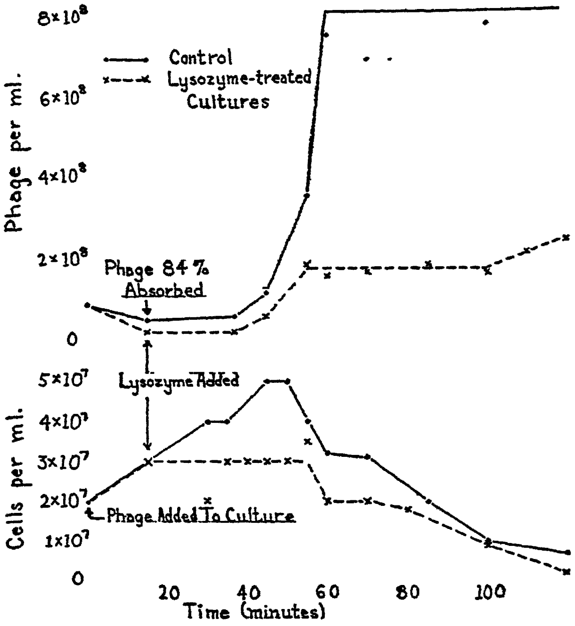

Fig. 1. Effect of addition of lysozyme to *Slophylococeus aureus* K^1 infected with P_1 phage.

Young (2½ hr.) cultures of *Staphylococcus aureus* K_1 in nutrient broth were infected with phage P_1. After 6-15 minutes egg white was added to experimental tubes and an equal volume of broth to the controls. The cultures were incubated at 37° with aeration, and aliquots were removed at intervals for assay. Figure I illustrates the findings in a representative experiment. The phage increase in control and lysozyme-treated cultures occurred at the same time, although a smaller increase was repeatedly observed with the latter. Efforts were made to determine whether lysozyme acted on infected cells. Unfortunately, a considerable portion (10-90 percent) of the bacteria were uninfected in spite of the fact that the phage to bacteria ratio was as high as 25 to 1. No conclusions were possible.

Use of lysozyme failed to provide evidence of phage increase prior to the normal time of lysis. The decrease in burst size in comparison with control cultures suggests the following possibilities: (a). lysis of some infected cells at a stage at which phage is incompletely formed and is therefore inactive, (b). destruction by lysozyme of some materials necessary for phage formation, or (c). action on cell walls, thereby changing their permeability and affecting the supply of nutrients to the cell.

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BOTANY

Chairman: H. J. BRODIE, Indiana University

R. A. Laubengoyer, Wabash College, was elected chairman for 1949.

ABSTRACTS

Variation in the bird's nest fungus, Cyathus Stercoreus, in culture and in nature. HAROLD J. BRODIE. Indiana University.—A long series of haploid mycelia, all derived from spores of a single peridiole of one wild type specimen of the cophrophilous fungus *Cyathus stercoreus,* when paired in certain combinations yielded diploid strains that differed from one another in color, texture and growth rate. A number of the diploid mycelia were induced to fruit in culture, and these produced fruit bodies of several different types, some so unlike the parental wild type as to bear little superficial resemblance to *C. stercoreus.* Ten of the culture types were planted outdoors in garden soil enriched with manure. Two such cultures fruited after six months, and in each instance produced fruit bodies essentially identical with those obtained in the laboratory. The extreme variability of this fungus noted in collections from nature probably has a genetic basis.

Growth patterns of carrot and sunflower roots cultivated in vitro. C. W. HAGEN, JR., Indiana University.—Excised carrot (Red-cored Chantenay) and sunflower (Mammoth Russian) roots may be cultured indefinitely in White's solution containing thiamine, pyridoxine, and nicotinic acid. Both species exhibit two growth patterns, a "normal" and a "hyperhydric" type. The normal differs from the hyperhydric in its higher growth rate, more regular contour, greater opacity, higher content of intercellular gas, and its tendency to float near the surface of the culture fluid. Parallel clones of the two types may be maintained provided the normal clone is repeatedly subcultured by excision of tips of lateral roots. Apical meristems of the normal type invariably transform to the hyperhydric type within ten weekly transfers. The reverse transition has never been observed. Some evidence bearing on the nature of the transition has been accumulated.

Right-handed and left-handed corn embryos. PAUL WEATHERWAX, Indiana University.—A seedling grass plant may be designated as right-handed or left-handed according to the direction in which the edges of the lowest leaf sheath overlap. An old publication on the structure of the ear of corn states that, in the normally paired rows of grains, the embryos in one row are right-handed and those in the other are left-handed. The problem has been reinvestigated and the statement found to be erroneous. Whether a corn plant is to be right-handed or left-handed is determined wholly by chance and is in no way correlated with the position of the embryo in the characteristic pair of grains.

The Devonian-Mississippian Transition Flora of Indiana and Kentucky. Part I: Geological Aspects. J. H. HOSKINS AND A. T. CROSS.—The flora of the black shales of southern Indiana and correlative beds in Kentucky, Tennessee, and Ohio is represented by abundant petrified fragments of wood preserved in phosphatic nodules or as isolated, phosphatized specimens embedded in the matrix which contains the nodules. These fossils are fairly numerous in certain areas of the outcrop of the black shales but they are known only from the upper few feet of this series, i.e., in that portion which is considered to be Mississippian in age.

The upper part of the Devonian portion of the black shale series contains the better known silicified trunks of Callixylon Newberryi, and the lower part contains a zone of abundant, carbonized compressions of Foerstia. These two plants are found in beds of equivalent and slightly earlier age in the Ohio Black shale and the Chattanooga shale. Other species of Callixylon are found in near-equivalent and somewhat older beds in New York and in the upper part (Mississippian) of the New Albany shale.

A few species of plants found in the phosphate nodule zone (L. Miss.) of this region are possibly similar to some species less well known from beds considered to be Upper Devonian, in age, from New York. In general, this flora corresponds to that recorded from similar black shale deposits of Europe, and is not easily identified as being typically Mississippian or Devonian. The flora represented here by the petrified wood may be the equivalent of one of the fairly well known Middle or Upper Devonian impression floras of eastern North America or/and Europe.

The Devonian-Mississippian Transition Flora of Indiana and Kentucky. Part II: Paleobotanical Aspects. J. H. HOSKINS AND A. T. CROSS.—The flora of the New Albany shale based on the structure of petrified plant fragments is comprised of about 35 genera and 50 species. This assemblage represents a Devonian-Mississippian transition flora, for it reflects to a certain extent the vegetation considered typical of Middle and Upper Devonian and it also includes a number of genera better known from the Mississippian and even later geologic periods. But by far the majority of species and even genera are known only from the New Albany shale or from rocks of comparable age and character.

The Pteropsida and Cycadofilicales are the most varied groups present and also the most abundant. The genera Kalymma, with a number of species, and Calamopitys are most commonly found. The morphology and range of 24 of the most common genera are reviewed and illustrated.

Increased Survival Value Resulting from Apparently Deleterious Mutations in Oenothera. RALPH E. CLELAND, Indiana University.—

Oenothera has suffered a number of kinds of alteration in its hereditary mechanism which would seem to militate against its success in the struggle for existence. Reciprocal translocations tend to result in non-disjunction and consequent reduction in fertility. Lethals reduce fertility drastically. Self-pollination tends to reduce heterozygosity and the beneficial effects of hybrid vigor. It would seem that plants possessing all three of these would be handicapped indeed. Instead, the groups of Oenothera which are characterized by all three are the most vigorous, the most fertile and the most widely distributed groups in the genus. Oenothera illustrates how it is possible for seemingly deleterious mutations to combine in such a way as to bring increased rather than decreased survival value. Thus, in Oenothera, translocations occur in such a way that they do not bring about significant reduction in fertility, and hence translocated chromosomes do not tend to become eliminated through selection. This brings about increased heterogeneity in segmental arrangement resulting in large circles. When circles are present, lethals become advantageous since a single pair of balanced lethals can preserve the heterozygosity of all of the chromosomes with minimal reduction in fertility, thus insuring the maximum of hybrid vigor. Self-pollination, by insuring heavy pollination, overcomes the sterilizing effect of the lethals, and in turn the lethals prevent self-pollination from reducing heterozygosity and hybrid vigor. Thus it is seen that mutations which by themselves are capable of producing harmful effects may, when properly combined, add up to increased survival value in the struggle for existence.

Forest Type Control in the Versailles Park Area Ripley County, Indiana. J. E. POTZGER, Butler University.—The Versailles Park area (Ripley County) differs somewhat from most locations in Indiana in that the microclimatic control of forest types is more complex because of the compact, leached flats habitat. North-facing slopes and gentle south-facing slopes have mixed mesophytic forest (with beech-maple tendencies), south-facing slopes are primarily oak-hickory, flood-plains have the usual sycamore-elm-hackberry association, and the compact, poorly drained flats are invaded primarily by the beech-sweet gum-red maple association. This latter type forest yields to the climax mixed mesophytic forest readily when stream cutting of a few feet in depth introduces better drainage, and no doubt better aeration of the soil. Significant features are that in this change beech and sour gum persists in the new association, sweet gum drops out completely, red maple, tulip poplar and white oak are reduced to scattered representation. The chief invader of the modified habitat is sugar maple, while red oak, black walnut, and linden become minor representatives in the new association complex. Physical characteristics of the soil and lack of adequate aeration appear to be the most vital edaphic factors in determining the establishment of the sweet gum-beech-red maple Illinoian tillplain forest type.

Forests Past and Present on Isle Royale (A preliminary report). J. E. POTZGER, Butler University.—Isle Royale in Lake Superior has at present a striking boreal type of forest in which black spruce and white spruce are perhaps the most important species. Associated with these conifers is white birch. The forest as a whole is marked by small stem-size of trees except for some arbor vitae in swampy locations. The present forest cover may very likely be a post-fire forest. This conclusion is also supported by pollen studies from bogs on the island. The initial forest was composed chiefly of black spruce and Jack pine, with very small representation of paper birch.

The Laboulbeniales: An Interesting but Rare Group of Fungi. HAROLD J. BRODIE, Indiana University.—Despite the extensive monographical work by Thaxter, few mycologists appear to have attempted to find or study the Laboulbeniales. These fungi may have considerable phylogenetic significance because of their supposed relationship to the Red Algae. Too little is known of the life cycle and cytology of the group and it is suggested that they should be sought and studied. The writer has found specimens of the Laboulbeniales twice in Central Canada and once near Ann Arbor, Michigan, on the wing covers of water beetles and caribid beetles. The fungi most commonly found were *Laboulbenia Gyrinidarum,* Thaxter, and *L. flagellata,* Peyritsch.

Establishment and Growth of Seedling Reproduction of Sugar Maple (Acer Saccharophorum)

Daniel DenUyl, Purdue University

Reproduction of sugar maple *(Acer saccharophorum)* is very common in the beech-maple woods of Indiana from which livestock have been excluded and which are not burned. Even in the oak-hickory woods sugar maple regeneration is commonly found along with elm, ash, hickory, and oak. The question that frequently arises is "What happens to the sugar maple seedlings and how many survive and grow into saplings, poles, and larger sized trees?" An answer to these questions comes from the records of permanent sample plots which were established in 1931. The purpose of these plots was to study the natural regeneration in woods from which livestock and fire were excluded. Quadrats 1/1000 acres in size were laid out and on these reproduction of all tree species was tagged. Measurements on many of the quadrats were taken annually for 5 years after which time periodic measurements were made. It is from these records that the establishment and growth habits of sugar maple will be described.

Sugar maple is a frequent and abundant seed producer. During the period 1931-1947 it was observed that in the woods where sample plots were located that 9 years out of 17 were good seed years.

Following an abundant seed crop thousands of newly germinated seedlings will be present in the woods. In some woods a dense carpet of seedlings numbering up to 1½ million per acre will become temporarily established. In other woods patches of dense sugar maple reproduction will be present. To illustrate what happens to the seedling population a record of one typical quadrat is presented.

Table 1. Sugar Maple Regeneration on a 1/1000 Acre Quadrat
Height Classes in Feet

Year	0.5	1	2	4	6	8	Totals
			Numbers of Seedlings				
1932	1350						1350
1933	600	15					615
1934	300	67					367
1935	232	96					328
1937	25	100	9				134
1938	34	110	19				163
1939	71	35	51	6			163
1940	44	49	34	35			162
1942	23	10	9	5	1		48
1944	18	8	6	6	2	1	41
1947	12	9	5	5	2	2	35

The number of sugar maple seedlings shown in the 0.5 foot height class does not represent all of the seedlings that start growing because measurements were taken in July or August and so some seedlings had already died before counts were made. Observations show that many seedlings become temporarily established but do not persist and grow into the larger height classes. The marked drop in numbers between 1935 and 1937 was in a large measure due to the hot dry season of 1936. Measurements were not made in August 1936 because most of the seedlings appeared to be dead. The record of 1937 and the years following indicate that many seedlings survived and some have grown into the larger height classes. The figures also show that the mortality is high even of maple that seems to be well established, as is indicated by the number present in 1947. Although the quadrat record shows 9 sugar maples four feet or more in height in 1947, it is apparent that this number will be reduced as competition for space becomes more intense.

To illustrate what may happen to sugar maple saplings a record of the growth of trees in the smaller diameter classes is shown for trees growing in a woods where sugar maple constitutes 60% of the trees in the overhead stand.

TABLE 2. Growth of Sugar Maple per Acre

Diameter Class	Number of Trees			
(inches)	1932	Percent	1947	Percent
1	12	26		
2-3	8	17	18	39
4-5	20	43	12	26
6-7	6	14	10	21
8-9			6	14
	46	100	46	100

Although there was no mortality of the trees during the 15 year period, there is a marked change in the diameter class distribution. As these smaller maples compete with the larger trees in the stand some of them will eventually die.

Records of individual trees shed some interesting light on the growth of sugar maple. A maple tree 5.1 inches dbh in 1932 grew to a diameter of 5.8 inches in 10 years. In 1942 competing trees were cut and this sugar maple added 1.2 inches to its diameter during the 5 years, 1942-47, which is almost twice the growth previous to the removal of its competitors. Numerous examples of a similar response could be given. However, not all trees respond in this way but this record illustrates that some trees may grow into the larger diameter classes while others of the same size may lose out in the competition or fail to respond to changed growing conditions. In many regeneration quadrats it was observed that other hardwood species may offer sugar maple serious competition for growing space. Elm is an interesting example and often the number of young sugar maple seedlings may be reduced as elm seeds in and becomes temporarily established.

Summary

An initial stand of over 1 million sugar maple seedlings per acre will be reduced in 15 years time to 35 thousand or less. Following this many decades of competition for growing space will result in the establishment of a sugar maple woods composed of approximately 40 sugar maple trees per acre with 30 to 40 other hardwood associates. For sugar maple to maintain its position in a beech-maple woods it appears that an initial establishment of large numbers of seedlings is necessary to insure a satisfactory distribution of saplings, poles, and young timber sized trees.

Notes on Indiana Liverworts—I*

KENNETH A. WAGNER, University of Tennessee

This paper begins a series dealing with the taxonomic, ecological, and other problems concerning the liverworts known to occur in Indiana. The results of two collecting trips in June 1947 are reported, together with other data compiled during the past year. Two species, *Cephalozia pleniceps* and *Riccardia palmata,* are reported for Indiana for the first time. All collections cited are deposited in the DePauw University herbarium and in the herbarium of the University of Tennessee.

Cephalozia pleniceps (Austin) Lindb. Parke Co., Turkey Run State Park, on sandy soil along Sugar Creek, Sept. 4, 1946, Wagner 1327; on sandstone along Sugar Creek, Sept. 4, 1946, Wagner 1318.

Cololejeunea Biddlecomiae (Austin) Evans. Union Co., on bar, woods 4 miles north of Liberty, June 6, 1947, Wagner 1409.

Conocephalum conicum (L.) Dum. Brown Co., on soil along stream, Brown County State Park, June 8, 1947, Wagner 1429. Huntington Co., Oct. 1946, Fred Loew.

Frullania eboracensis Gottsche. Blackford Co., on bark, woods 6-7 miles northwest of Pennville, June 4, 1947, Wagner 1403. Jay Co., on tree, 2 miles north of Red Key, June 4, 1947, Wagner 1422.

Frullania riparia Hampe. Brown Co., on bark, Brown County State Park, June 9, 1947, Wagner 1433. Randolph Co., with moss, 8 miles south of Union City, June 8, 1947, Wagner 1404. Wells Co., on tree trunk, woods 3 miles west of Poneto, June 4, 1947, Wagner 1418.

Lophocolea heterophylla (Schrad.) Nees. Blackford Co., on decayed wood, 6-7 miles northwest of Pennville, June 4, 1947, Wagner 1401. Brown Co., on humus, Brown County State Park, June 8, 1947, Wagner 1423. Jay Co., on decayed wood, 2 miles north of Red Key, June 4, 1947, Wagner 1420.

Metzgeria conjugata Lindb. was first reported for Parke County by Dorothy Parker in volume 51 of the proceedings of this Academy. The location of the collection was Turkey Run State Park. The present writer also collected this species at Turkey Run (Wagner 1325) and examined 26 other collections, all from that same area. Why only one station has been found for this species in Indiana presents a problem and the answer is not apparent at this time. The range of *M. conjugata* is rather general in the United States. It occurs from Maine to Florida and Louisiana, in the Pacific coast states, in Tennessee, Kentucky, Indiana and Wisconsin. It might be found in cool sandstone raivnes such as occur at Fern and Fallen Rock, and all collectors should look for it.

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* Contributions from the Botanical Laboratory, The University of Tennessee.

Porella platyphylla (L.) Lindb. Blackford Co., in woods, 6-7 miles northwest of Pennville, June 4, 1947, Wagner 1402.

Porella platyphylloidea (Schwein.) Lindb. Brown Co., on tree base, Brown County State Park, June 8, 1947, Wagner 1431. Jay Co., in woods, 2 miles north of Red Key, June 4, 1947, Wagner 1420. Posey Co., May 13, 1934, W. H. Welch 7820. Union Co., on tree base, woods 4 miles north of Liberty, June 8, 1947 Wagner 1408.

Preissia quadrata (Scop.) Nees. Brown Co., on damp hillside, Brown County State Park, June 9, 1947, Wagner 1431.

Reboulia hemisphaerica (L.) Raddi. Brown Co., on soil, Brown County State Park, June 8, 1947, Wagner 1425.

Depauperate growth of this species is easily confused with similar growth of *Preissia quadrata.* Examination of a good cross section of the thallus will enable the observer to readily distinguish between these two species, but such sections are sometimes difficult to make, especially for the beginner. The writer examined numerous collections of both species and found that there is a consistent difference in the rhizoids which can be observed with a handlens. When dry, the rhizoids of *R. hemisphaerica* glisten; those of *P. quadrata* do not. This difference in light reflection apparently is due to the greater number of pegs in the rhizoids of the former species. The rhizoids are also smaller, ranging from 6 to 21 microns in cross section, the majority being about 15 microns. The rhizoids of *P. quadrata* range from 7 to 37 microns in cross section, the majority being from 20 to 30 microns.

Scapania nemorosa (L.) Dum. Brown Co., on soil along stream, Brown County State Park, June 9, 1947, Wagner 1432.

Notes on Indiana Liverworts—II. Porella in Indiana*

KENNETH A. WAGNER, University of Tennessee

PORELLA L.

Plants dark green to brown, 1-7 mm. wide, 1-12 cm. long, often forming extensive but rather loose mats; stems 1-3 pinnately branched; rhizoids wanting to numerous, arising from the base of the underleaves. Leaves incubous, complicately bilobed, the dorsal lobe larger; median leaf cells of the dorsal lobe 18-36 microns in diameter, approximately isodiametric; underleaves always present, conspicuous. Gemmae are reported for only a few tropical species. Plants dioecious. Male and female inflorescences on short lateral branches, and, in both, the lobes of the bracts about equal in size. Perianth large, often 2 lipped.

Key to the species

A. Plants growing submerged, 2-4 mm. wide . . . . . . *P. pinnata*

AA. Plants not growing submerged, 2-7 mm. wide.

    B. Plants 4-7 mm. wide; lobule lanceolate to linear-oblong, its width less than one half that of the underleaf; insertion of the underleaf transverse; trigones of the leaf cells bulging; median leaf cells 24-35 microns . . . . . . *P. pinnata*

    BB. Plants about 2 mm. wide; lobule lingulate, its width at least half that of the underleaf, often equal to or wider than the underleaf; insertion of the underleaf crescentic; trigones of the leaf cells prominent but not bulging; median leaf cells 16-26 microns . . . . *P. platyphylla*

P. pinnata is easily identified by the very small, narrow ventral lobes. It occurs on tree bases and exposed roots, occasionally on limestone and cement. Usually it is found in a more moist habitat than is *P. platyphylla.* It appears twice in the above key because of differences between the submerged and terrestrial plants. Those plants growing in water are much narrower, and the leaf cells are correspondingly smaller, ranging from 18 to 26 microns in diameter.

Recent literature on Indiana liverworts lists another specific name, *platyphylloidea,* in the genus *Porella.* In 1947 the author reported this as a species from 15 counties (4). The majority of identifications of *P. platyphylla* and of *P. platyphylloidea,* however, were always accompanied by some uncertainty. Following the work of Ammons (1) and Evans (2), the specimens were referred to whichever species the majority of the plant seemed to fit. Evans has pointed out that all of the vegetative characteristics intergrade between the two extreme forms. Figures 2 and 3 represent such extremes and are not difficult to classify in a system which maintains the validity of both *P. platyphylla* and *P. platyphylloidea.* There is difficulty, however, when an attempt is made to refer to one species a plant having characteristics of both extremes. Figures 4 and 5 were drawn from the same plant.

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* Contributions from the Botanical Laboratory, The University of Tennessee, N. Ser. 106.

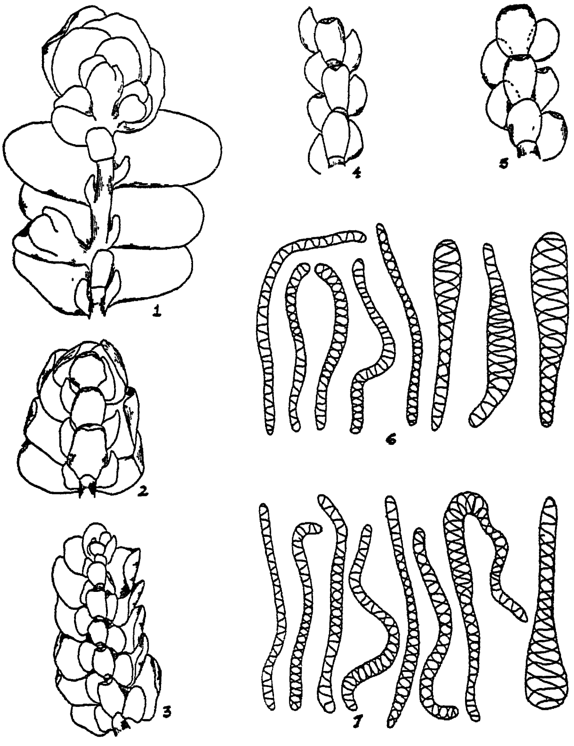

Fig. 1. *Porella pinnata,* ventral surface. Fig. 2 and 3, extreme forms of *P. platyphylla.* Fig. 4 and 5, underleaves and lobules from two branches of the same plant. Fig. 6, elator types from a plant similar to Fig. 2. Fig. 7, elator types from a plant similar to Fig. 3.

Evans' final conclusion is that the elators alone show consistent differences in the two species. He restricts the name *P. platyphylla* to those plants producing only bispiral elators. The elators of *P. platyphylloidea* have a single spiral in the majority of cases. He notes that rarely elators are found to have two spirals in the middle, but are never bispiral throughout.

Frye and Clark (3), in reducing *P. platyphylloidea* to a variety of *P. platyphylla,* put somewhat different limitations on the elators. *P. platyphylla* is described as having elators with 1-3, usually 2 spirals to the end. The variety, then, has elators with only 1 spiral for half the length, or throughout.

Figure 6 shows the types of elators found in the capsules of a plant having the gametophytic characteristics of *P. platyphylla*. Figure 7 shows elator types of a plant which, otherwise, would key to *P. platyphylloidea*, or to the variety if Frye and Clark is followed.

These diagrams show that the spirals of the elators cannot be used to separate the blunt lobuled forms either as a distinct species or as a variety. In view of this situation plus the fact that the vegetative extremes may be found on the same plant, it is believed that *P. platyphylloidea* (Schwein.) Lindb. and *P. platyphylla* var. *platyphylloidea* (Schwein.) Frye and Clark should be listed as synonyms of *P. platyphylla* (L.) Lindb.

In making this reduction, only the following seven Indiana counties must be added to the list of those already published for *P. platyphylla*: Brown, Jay, Morgan, St. Joseph, Scott, Union, and Washington. This brings to 44 the total number of counties in Indiana in which this species has been found. There is no reason to believe, though, that it does not occur in every county.

REFFERENCES

1. Ammons, N., A manual of the liverworts of West Virginia. Am. Mid. Nat. **23**, 3-164, 1940.

2. Evans, A. W., Notes on New England hepaticae—XIII. Rhodora **18**, 82-85, 103-106, 109-119. 1916.

3. Frye, T. C. and L. Clark, Hepaticae of North America. Univ. of Wash. pub. in Biology **6**, 721-724. 1946

4. Wagner, K. A., Additional distribution records of hepaticae in Indiana. Proc Indiana Acad. Sci. **56**, 86-91. 1947.

Higher Fungi of Marion County, Indiana

JOHN O. COTTINGHAM, Indianapolis, Indiana

The following is a list of fleshy, leathery and woody fungi which have been found by my assistants and myself since my report to the Indiana Academy of Science, October 1947. Our report at that time listed 192 species. We are now adding 46 more or a total of 238 species thus far found and identified in Marion County. Many species that should be indigenous have not yet been found and while this list is very incomplete, it does give the mycologist a good idea of what he may expect to find most frequently in the center of Indiana.

AGARICACEAE

Agaricus arvensis, Fr.; *Collybia fusipes* (Bull); *Collybia maculata*, A. & S.; *Collybia hariolorum*, Fr.; *Clitopilus popinalis*, Fr.; *Clitocybe dealbata*, Fr.; *Cortinarius duracinus*, Fr.; *Hygrophorus flavo-discus*, Frost.; *Lactarius piperatus*, Fr.; *Lentinus Ursinus*, Fr.; *Lenzites vialis*, Pk.; *Mycena alcalina*, Fr.; *Marasmius foetidus*, Sow.; *Panus stipticus*, Bull.; *Pholiota rugosa*, Pk.; *Pholiota squarrosa*, Müll.; *Pholiota mutabilus*, Schaeff.; *Pholiota curvipes*, Fr.; *Psilocybe foenisecii*, Fr.; *Russula ochrophylla*, Pk.; *Tricholoma sulphureum*, Fr.; *Tricholoma album*, Schaeff.; *Collybia hygrophoroides*, Pk.

POLYPORACEAE

Polyporus Berkeleyi, Fr.; *Polyporus pensylvanicus*, Sumst.; *Polyporus chioneus*, Fr.; *Polyporus radiatus*, Fr.; *Polyporus pergamenus*, Fr.; *Polyporus frondosus*, Fr.; *Polyporus fumosus*, Fr.; *Polyporus tephroleucis*, Fr.; *Polyporus sanguineus*, Fr.; *Boletus bicolor*, Pk.; *Boletus luteus*, L.; *Poria corticola*, Fr.; *Poria attenuata*, Pk.; *Poria medulapanis*, Pers.; *Trametes rigida*, Bert. and Mont.

LYCOPERDACEAE—*Calvatia gigantea*, Pers.

HYDNACEAE

Hydnum erinaceus, Bull.; *Hydnum albonigrum*, Pk.; *Hydnum ochraceum*, Pers.

THELOPH ORACEAE—*Sterum rameale*, Schw.

ASCOMYCETES—*Peziza vesiculosa*, Bull.

Studies in the Stromatic Sphaeriales of Indiana—II[1]

EMORY G. SIMMONS, DePauw University

This paper is the second in a series of taxonomic reports covering the stromatic members of the order *Sphaeriales*. An attempt is made here to organize and to complete, where possible, the scattered and often unrelated or incomplete data concerning the Indiana species of the family *Diatrypaceae*, and to present it in such a manner that it will form a workable basis for future taxonomic investigation or for classroom determination of collections.

During the preparation of this study specimens were available from the following institutions: DePauw University (DPU)[2]; Indiana University (IU); Miami University (MU); New York Botanical Garden (NY); and Wabash College (WAB).

DIATRYPACEAE

Diatrypeae Winter, in Rabenhorst, *Kryptogamen-Flora.* 1 (Div. II): 810. 1887.

Diatrypaceae Lindau, in Engler and Prantl, *Die Natürlichen Pflanzenfamilien.* 1 (Div. I): 472. 1897.

Stromata composed entirely of fungus elements (stroma and host not mixed), effused, pulvinate, shield-shaped, or tuberculiform. Conidial and ascigerous stages characteristically on different stromata. Perithecia monostichous or polystichous with their ostiola separately erumpent. Ascospores small, cylindrical, usually curved, allantoid, hyaline or light brown unicellular.

Key to the Genera

Asci 8-spored	*Diatrype*
Asci with more than 8 spores	*Diatrypella*

DIATRYPE Fries

Diatrype Fries, Summa Veg. Scand. 385. 1849.

Valseutypella Hoehnel, Ann. Mycol. 16:224. 1918.

Ectosphaeria Spegazzini, Bol. Acad. Cordoba, 25:48, ill. 1921.

Stromata effused or isolated, ectostroma deciduous, exposing a widely erumpent entrostromatic disk. Perithecia parallel, separately erumpent. Ascospores eight, allantoid, yellowish. Imperfect stage ectostromatic.

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[1] A portion of a major thesis (A Monographic Study of the Indiana Species of the Stromatic Sphaeriales) presented to the Faculty of the Department of Botany, DePauw University, in partial fulfillment of the requirements for the degree Master of Arts, June 1946.

[2] These abbreviations are used in locating specimens referred to in the citations following each species description throughout this paper.

Key to the Species

1. Stromata greenish-yellow.... .... .7. *D. virescens*
   Stromata (mature) light brown to black 2
2. Stromata 2 cm. in length to widely effused 3
   Stromata variously pulvinate but not exceeding 4 mm. in longest diameter 4
3. Perithecia closely packed; asci (sp. p.)[3] 25-30 microns long.. .. . . 5. *D. platystoma*
   Perithecia evenly distributed; asci (sp. p.) 30-50 microns long . .. . 6. *D. stigma*
4. Ascospores 12-16 microns long . ... 1. *D. albopruinosa*
   Ascospores not exceeding 12 microns in length 5
5. Asci (sp. p.) 40-45 microns long .. 4. *D. hochelagae*
   Asci (sp. p.) less than 40 microns in length 6
6. Ostiola prominent, erumpent; stromata 1.5-2.5 mm. in diameter . . .. .2. *D. asterostoma*
   Ostiola small, obtusely conical, slightly projecting; stromata 2-3 mm. in diameter ....3. *D. disciformis*

1. *Diatrype albopruinosa* (Schweinitz) Cooke

Sphaeria albopruinosa Schweinitz, Syn. fung. N. Am. 195. 1831.

Diatrype albopruinosa (Schweinitz) Cooke, Grevillea, 13:37. 1885.

Diatrype roseola Winter, Journ. Mycol. 1:121. 1885.

Diatrype Durieui Montagne, in Herb. Curtis (fide Ellis & Everhart, N. Am. Pyr. 570. 1892.)

Diatrype Webberi Ellis & Everhart, in Herb. E. & E. (fide Ellis & Everhart, N. Am. Pyr. 570. 1892.)

Eutypella sheariana Berlese, Icon. Fung. 3:68. 1905.

Stromata scattered or subgregarious, sometimes confluent, suborbicular, 1.5-2.5 (exceptionally 3-4 mm. broad, slightly convex, surrounded by the ruptured epidermis, whitish when young and fresh, becoming finally dark brown, light-colored inside, surface becoming more or less fissured. Perithecia 10-30 in a stroma, crowded ovate or elliptic-oblong. Ostiola more or less prominent, 3-5 sulcate-cleft, black. Asci oblong-clavate, long-stipitate, sp. p. 55-65 x 7 microns. Ascospores heaped together, allantoid, obtuse, slightly curved, 12-16 x 2.5-4 microns, yellow-brown.

Specimens examined:

Clay Co.: May 19, 1928, Shaw (IU).

Monroe Co.: on oak, Bloomington, April 1909, Wood (IU).

Tippecanoe Co.: on oak wood, Lafayette, April 18, 1899, C. Riddle (MU).

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[3] Sp. p. is used here to indicate measurements of the spore-containing portion of the ascus.

Most of the non-effused species of Diatrype are separated with difficulty because of their macroscopic resemblances to each other. Spore and ascus measurements remain the best differential characters and are effective in separating *D. albopruinosa* (Schw.) Cke. from similar species. The asci and ascospores of *D. albopruinosa* are constantly larger than are those of *D. hochelagae* E. & E., *D. disciformis* (Hoffm.) Fr., and *D. asterostoma* Berk. & Curt.

2. *Diatrype asterostoma* Berkeley & Curtis

Diatrype asterostoma Berkeley & Curtis, Grevillea, 4:96. 1875.

Stromata wart-like, erumpent, scattered or subconfluent, 1.5-2.5 mm. in diameter, embraced at the base by the ruptured epidermis, externally black (white inside). Perithecia 10-20 in a stroma, globose, black, abruptly contracted into slender necks rising through the white substance of the stroma, with prominent, stellate-cleft, erumpent ostiola. Asci clavate, long-stipitate, sp. p. 25 x 4-5 microns, 8-spored. Ascospores allantoid, nearly hyaline, moderately curved, 6-10 x 1.5-2 microns.

Specimens examined:

Montgomery Co.: Rattlesnake Ravine, S. W. Crawfordsville, April 13, 1946, Simmons 1251 (DPU).

Morgan Co.: on fallen beech limb, ravine N. E. Martinsville, Sept. 20, 1941, Simmons 1252 (DPU).

Union Co.: on beech twigs, in open pasture, July 21, 1917, Fink 26 (MU).

This species is readily separated from *D. albopruinosa* (Schw.) Cke. and *D. hochelagae* E. & E. by reason of its smaller asci. However, distinctions made between *D. asterostoma* Berk. & Curt. and *D. disciformis* (Hoffm.) Fr. are so slight that *D. asterostoma* appears to be little more than a variety of D. disciformis. Differentiation between the two is made by means of the smaller stromata and more prominent ostiola of *D. asterostoma.*

3. *Diatrype disciformis* (Hoffmann) Fries

Sphaeria disciformis Hoffman, Veg. Crypt. 1:15. 1787.

Sphaeria depressa Sowerby, Eng. Fung. Vol. 2, pl. 216. 1799.

Sphaeria grisea DeCandolle, Flore Fr. 2:122. 1805.

Diatrype disciformis (Hoffman) Fries, Summa Veg. Scand. 385. 1849.

Stromata scattered or gregarious, flattened-pulvinate, round, 2-3 mm. in diameter, discoid, erumpent and loosely embraced by the ruptured epidermis, dark brown, whitish inside, base sunken to the wood and circumscribed by a black line. Perithecia 20-30 (or more) in a stroma, ovate, about 0.75 x 0.5 mm., closely packed and subangular, with short necks and small, obtusely conical, smooth or 3-5-cleft, slightly projecting ostiola. Asci clavate, long stipitate, sp. p. 22-30 x 4-5 microns. Ascospores subbiseriate, allantoid, yellowish, slightly curved, 6-8 x 1.5-2 microns.

Specimens examined:

Montgomery Co.: on bark of dead limb, below dam, Sugar Creek, Crawfordsville, Spring, 1929, A. R. Bechtel 832 (WAB).

Ascus measurements of *D. disciformis* (Hoffm.) Fr. serve to distinguish it from both *D. albopruinosa* (Schw.) Cke. and *D. hochelagae* E. & E. Characteristics of *D. disciformis* and of *D. asterostoma* Berk. & Curt., as have been stated in previous remarks, are so similar, however, that varietal placement of *D. asterostoma,* if not actual synonymy, should be the proper treatment of the two.

4. *Diatrype hochelagae* Ellis & Everhart

Diatrype hochelagae Ellis & Everhart, Proc. Acad. Nat. Sci. Phil. 42:224. 1890.

Stromata orbicular or elongated, 2-3 mm. long and 1-2 mm. wide, often more or less confluent, pulvinate-verrucose, with the margin abrupt or slanting off at the ends, with a faint circumscribing black line which does not penetrate deeply into the wood, dull black outside, dirty white within. Perithecia crowded in the stroma, subglobose, about 0.5 mm. in diameter, with black, thick, leathery walls. Ostiola conic-hemispherical, deeply 4-5 sulcate-cleft. Asci (sp. p.) 40-45 x 7-8 microns, with stout paraphyses. Ascospores allantoid, yellowish, moderately curved, 8-12 x 2.5 microns.

Specimens examined:

Monroe Co.: on pear, Bloomington, Feb. 12, 1931, Amidei (IU).

Mature stromata of *D. hochelagae* E. & E. are scarcely separable from those of *D. albopruinosa* (Schw.) Cke. by macroscopic means. However, the differences between the two with respect to spore and ascus measurements (pointed out in the key to the species) are so constant that there is little probability of confusing these species.

5. *Diatrype platystoma* (Schweinitz) Ellis & Everhart

Sphaeria platystoma Schweinitz, Syn. fung. Car. 43. 1822.

Diatrype discostoma Cooke, Grevillea, 6:144. 1878.

Diatrype platystoma (Schweinitz) Ellis & Everhart, N. Am. Pyr. 566. 1892.

Stromata effused or, oftener, in suborbicular patches 1-2 cm. across or elongated 2-4x0.5-1 cm., soon erumpent, about 1 mm. thick, margin abrupt, slaty-black or black. Perithecia monostichous, ovate-oblong, 0.5-0.75 mm. high, closely packed. Ostiola prominent, hemispherical, entire or 4-sulcate. Asci (sp. p.) 25-30 x 4 microns, stipitate. Ascospores subbiseriate, allantoid, hyaline, 6-8 x 1.5 microns.

Specimens examined:

Monroe Co.: on maple, Bloomington, 1911, Owens (IU).

Morgan Co.: on decaying, decorticated wood, ravine N. E. Martinsville, Sept. 20, 1941, Simmons 1141 (DPU); on loosened bark of dead beech limb, ravine N. E. Martinsville, Sept. 20, 1941, Simmons 1147 (DPU).

Putnam Co.: on dead herbaceous stem, DePauw Arboretum, Oct. 25, 1945, Simmons 1136 (DPU); on dead limbs of ironwood, DePauw Arboretum, Oct. 25, 1945, Simmons 1138 (DPU); on fallen, rotting elm limb, DePauw Arboretum, Nov. 13, 1941, Simmons 1140 (DPU); on fallen oak branch, valley E. Bainbridge, Oct. 17, 1941, Simmons 1142 (DPU); on dead branch of beech, DePauw Arboretum, Nov. 13, 1941, Simmons 1144 (DPU); on upright weathered post, Hoosier Highlands, Sept. 16, 1941. Simmons 1160 (DPU).

Specimens of *D. platystoma* (Schw.) E. & E. and *D. stigma* (Hoffm.) Fr. frequently are found to be separated with difficulty. Both are effused forms of Diatrype and both become black or nearly black at maturity. *D. platystoma* usually is noticeably the more coarse of the two by reason of its slightly larger perithecia and ostiola. Ascus measurements show these of *D. platystoma* to be less than those of *D. stigma.*

6. *Diatrype stigma* (Hoffman) Fries

Sphaeria stigma Hoffman, Veg. Crypt. 1:7. 1787.

Sphaeria decorticans Sowerby, Eng. Fungi, Vol. 2, pl. 137. 1799.

Sphaeria decorticata DeCandolle, Flore Fr. 2:289. 1805.

Sphaeria undulata Fries, Syst. Mycol. 2:350. 1823.

Diatrype undulata Fries, Summa Veg. Scand. 385. 1849.

Diatrype stigma (Hoffman) Fries, Summa Veg. Scand. 385. 1849.

Stictosphaeria Hoffmanni Tulasne, Sel. fung. carp. 2:49. 1863.

Diatrype stigma Cesati & DeNotaris, Schema Sfer. Ital. 26. 1863.

Eutypa micropuncta Cooke, Grevillea, 6:144. 1878.

Diatrype Dearnessii Ellis & Everhart, in E. & E. North American Fungi, 2nd Ser. #2526. (fide Ellis & Everhart, N. Am. Pyr. 565. 1892.)

Diatrype tennissima Cooke, in Ravenel, Fungi Americani. (fide Ellis & Everhart, *loc. cit.).*

Sphaeria concolor Schweinitz, in Herb. Schweinitz. (fide Ellis & Everhart, *loc, cit.).*

Sphaeria subcutanea Wahlenberg, in Herb. Schweinitz. (fide Ellis & Everhart, *loc, cit.*)

Stromata widely effused, continuous or interrupted, often surrounding the limb, sometimes extending for several inches in length, at first covered by the epidermis, finally exposed, brownish or dusty-white, becoming darker or nearly black, whitish inside, definitely limited but irregular in outline, 0.5-1 mm. thick, sometimes undulate and of unequal thickness, the thinner parts then often sterile. Perithecia monostichous, evenly distributed, ovate, small, with short necks and punctiform, discoid, depressed-hemispherical or conical, entire or 4-cleft ostiola. Asci clavate-oblong, 8-spored, sp. p. 30-50 x 4-8 microns. Ascospores subbiseriate, allantoid, brownish, 6-9 x 1-1.5 microns.
Specimens examined:

Montgomery Co.: in Crawfords' Wood, Crawfordsville, Jan. 25, 1917, D. P. Miller (MU, WAB); Turners' Wood, S. W. Crawfordsville, May 21, 1941, Simmons 1101 (DPU).

Putnam Co.: on fallen branches, Hoosier Highlands, Sept. 16, 1941, Simmons 1137 (DPU).

Wabash Co.: on dead beech, Roann, March 20, 1908, Daisy G. Lewis (DPU).

This species is often collected in Indiana during its young stages, at which time the stroma is light brown or dusty-white in color. It commonly is found to encircle completely small dead branches. It can be separated from *D. platystoma* (Schw.) E. & E., which it greatly resembles, by reason of its constantly larger asci.

7. *Diatrype virescens* (Schweinitz) Ellis & Everhart

Sphaeria virescens Schweinitz, Syn. fung. N. Am. 195. 1831.

Diatrype disciformis (Hoffman) Fries var. *virescens* Berkeley, Grevillea, 4:95. 1875.

Diatrype virescens (Schweinitz) Ellis & Everhart, N. Am. Pyr. 569. 1892.

Stromata scattered, erumpent-superficial, orbicular, about 2 mm. in diameter, depressed-pulvinate, surrounded at the base by the ruptured epidermis; disk greenish-yellow, powdery, becoming darker with age. Perithecia monostichous, covered by the waxy, whitish substance of the stroma, about 0.33 mm. in diameter, 10-15 in a stroma, necks terminating in obstusely conical, 4-cleft, black ostiola barely erumpent through the greenish disk. Asci (sp. p) about 35 x 5 microns, stipitate, 8-spored. Ascospores subbiseriate, allantoid, yellowish, moderately curved, 7-9 x 1.5-2 microns.

Specimens examined:

Monroe Co.: on beech, Bloomington, July, 1938, Lohman (IU).

Montgomery Co.: on dead branches, Crawfordsville, H. W. Anderson (MU); on *Tilia sp.*, Camp Rotary, near Crawfordsville, Nov. 18, 1945, A. R. Bechtel (DPU); on dead beech branches, Lybyar farm, S. W. Crawfordsville, Nov. 22, 1941, Simmons 1146 (DPU).

Putnam Co.: on beech limb, Greencastle, Jan. 22, 1908, Daisy G. Lewis (DPU); Fern, Sept. 1893, L. M. Underwood (DPU); on dead beech limb, Greencastle, May 25, 1908, Daisy G. Lewis (DPU).

D. virescens (Schw.) E. & E. is rarely confused with any other pulvinate species of Diatrype. The small yellow-green, cushion-like stromata are found to retain their color for many years under herbarium conditions, specimens examined in the course of this study often being as much as 38 years old.

DIATRYPELLA Cesati & DeNotaris

Diatrypella Cesati & DeNotaris, Schema Sfer. Ital. 29. 1863.

Stromata effused or isolated, ectostroma absent or strongly developed but not deciduous; entostroma well developed, often pustulate but usually not widely erumpent, bounded by a dark marginal zone. Perithecia usually clustered, rarely separately erumpent. Ostiola usually sulcate. Asci long-stipitate, polysporous. Ascospores 1-celled, allantoid, yellow-hyaline. Imperfect stage primarily ectostromatic.

Key to the Species

1.	Asci large, more than 80 microns long	4. *D. quercina*
	Asci less than 80 microns long	2
2.	Asci less than 60 microns long	3. *D. prominens*
	Asci more than 60 microns long	3
3.	Ostiola 3-4 stellate-cleft; entostroma whitish	1. *D. Cephalanthi*
	Ostiola entire; entostroma greenish	2. *D. Frostii*

1. *Diatrypella Cephalanthi* (Schweinitz) Saccardo

Sphaeria Cephalanthi Schweinitz, Syn. fung. Car. 7. 1882.

Diatrypella Cephalanthi (Schweinitz) Saccardo, Syll. fung. 1:209. 1882.

Stromata scattered, 2-3 mm. in diameter, scarcely penetrating to the wood, at first small and subtubercular-erumpent, black, apex generally traversed by a single longitudinal, deep furrow (giving the appearance of an Hysterium), but this furrow soon obliterated as the apex of the stroma protrudes itself still further, assuming an orbicular or elliptical form, 1-3 mm. in diameter, and roughened by the protruding, black, rough subconical ostiola which are 3-4 stellate-cleft. Perithecia 6-20 in a stroma, closely packed, ovate or subangular, about 0.5 mm. in diameter, lying in and covered by the scanty whitish substance of the stroma; walls thick, black leathery; necks short. Asci fusoid, 110-115 (sp. p. 75-80) x 8-10 microns, polysporous, stipitate, paraphysate. Ascospores allantoid, yellow-hyaline, not strongly curved, 6-9 x 1.5 microns.

Specimens examined:

Putnam Co.: on Cephalanthus, Fern, December 1892, L. M. Underwood (NY). determined by Ellis as "*Diatrype Cephalanthi?*"

The collection cited above is still in excellent condition and yields numerous multi-spored asci and the subhyaline, slightly curved ascospores typical of species of Diatrypella.

The stromatic pustules of Diatrypella species are so similar to each other and to pulvinate species of Diatrype that determination of members of this group depends almost entirely upon ascus observations. *D. Cephalanthi* (Schw.) Sacc., as it is described, can be separated from *D. quercina* (Pers.) Nke. and *D. prominens* (Howe) E. & E. by ascus measurements and from *D. Frostii* Peck by reason of its whitish entostroma and stellate-cleft ostiola in contrast to the greenish entostroma and entire ostiola of *D. Frostii.*

2. *Diatrypella Frostii* Peck

Diatrypella Frostii Peck, Bot. Gaz. 3:35. 1878.

Stromata wart-like, 1-2 mm. in diameter, seated on the inner bark which is slightly blackened and marked around each stroma with a circumscribing line penetrating to the wood, erumpent, surrounded and partly covered (except the apex) by the ruptured epidermis, black outside, greenish within, forming a white spot on the wood beneath. Perithecia ovate-globose, 10-15 in a stroma, 0.33-0.5 mm. in diameter. Ostiola vary from obtuse-conical to subelongated, conic-cylindrical, entire, often obscure. Asci polysporous, cylindric-clavate, stipitate, paraphysate, sp. p. 75-80 x 12-15 microns. Ascospores yellowish, allantoid, moderately curved, 7-8 x 2 microns.

Specimens examined:

Monroe Co.: on *Acer sp.*, Bloomington, Amidei (IU).

D. Frostii Peck, as is true with other species of Diatrypella, can best be determined by means of ascus measurements. Separation from *D. Cephalanthi* (Schw.) Sacc., which it greatly resembles, is by its characteristically greenish entostroma and entire ostiola.

3. *Diatrypella prominens* (Howe) Ellis & Everhart

Diatrype prominens Howe, Bull. Torr. Bot. Club, 5:42. 1874.

Diatrypella prominens (Howe) Ellis & Everhart, N. Am. Pyr. 592. 1892.

Stromata wart-like, orbicular or angular, 1-1.5 mm. in diameter, erumpent and closely encircled by the ruptured epidermis, subprominent, black outside, whitish inside. Perithecia 4-8 in a stroma, subglobose, about 0.33 mm. in diameter, necks short, with their ostiola obtusely conical, slightly prominent and finally broadly and irregularly perforated. Asci clavate-stipitate, 75-80 (sp. p. 40-60) x 10-12 microns, paraphysate, polysporous. Ascospores allantoid, yellow-hyaline, moderately curved, 6-8 x 1.0-1.5 microns.

Specimens examined:

Monroe Co.: on sycamore, Bloomington, April 13, 1910, J. M. Van Hook 2768 (IU).

Montgomery Co.: on dead sticks, Crawfords' Wood, near Crawfordsville, Aug. 27, 1917, Fink & Fuson 272 (MU).

Certain determination of this species, as is pointed out in the key to species of Diatrypella, depends almost entirely on ascus measurements. Asci of *D. prominens* (Howe) E. & E. are constantly less than 60 microns in length, the shortest ones to be found among the species reported for Indiana.

4. *Diatrypella quercina* (Persoon) Nitschke

Sphaeria quercina Persoon, Syn. meth. fung. 24. 1801.

Diatrype quercina Fries, Summa Veg. Scand. 385. 1849.

Diatrypella Rousselii Cesati & DeNotaris, Schema Sfer. Ital. 32. 1863.

Diatrypella quercina (Persoon) Nitschke, Pyr. Germ. 71. 1867.

Stromata erumpent, surrounded by the substellate-cleft, adherent epidermis, pulvinate, orbicular or angular, rugose, thick; disk plano-convex, becoming black, mostly solitary but sometimes 2-3 confluent, 2-4 mm. in diameter. Perithecia 2-15 in a stroma, in a single or double layer, ovoid or subangular from compression, 0.5-0.75 mm. in diameter, attenuated into rather long necks rising through the grayish-white substance of the stroma with their conic-hemispherical, quadrisulcate ostiola distinctly erumpent. Asci clavate-fusoid long-stipitate, sp. p. 80-100 x 9-10 microns. Ascospores numerous, allantoid, yellowish, strongly curved, 8-12 x 2-3 microns.

Specimens examined:

* Putnam Co.: on dead oak, near Big-Four Springs, Greencastle, May 27, 1908, Daisy G. Lewis (DPU).

The relatively large asci of *D. quercina* (Pers.) Nke. (sp. p. 80-100 microns in length) readily distinguish it from other members of the genus. The multi-spored asci are easily made out, thus precluding the possibility of confusion of the species with members of the genus Diatrype.

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Indiana Plant Distribution Records, IX. 1948

Genera are listed in the order used in Deam's "Flora" and species are given in alphabetical order within the genera. Symbols following the county indicate the herbaria in which confirming specimens have been deposited. Entities new for the state are given in bold face followed by literature references and name of collector. Cases of doubt whether a taxionomic entity, newly found within the state, will become a part of the state flora are preceded by an asterisk.

The specimens listed below have been collected by the following collectors: Ball State Teachers College (BS): Mrs. Marian Rector; Butler University (B): Ray C. Friesner, Fred Loew, John E. Potzger, William Reynolds, Jack Secor, Frances Shockley, Homer H. Smith and Floyd A. Swink; Deam Herbarium (D): Charles C. Deam, Ray C. Friesner, and Floyd A. Swink; Gray Herbarium (G): Edwin D. Hull; Huntington College (Hu): Fred Loew; Indiana University (IU): Medford E. Campbell, Charles Heiser, and Arthur L. Reed; Wabash College (W): Dr. A. Clapp.

The committee maintains a card file showing published distribution of each species within the state. Botanical workers needing such information may obtain distribution maps of any species recorded in the Flora, or subsequently added in these reports, by requesting same from the secretary of this committee.

SPECIES

Botrychium dissectum v. *obliquum*, Clay (B). *Osmunda claytoniana*, Delaware (BS). *O. regalis* v. *spectabilis*, Clay (B). *Cystopteris fragilis* v. *protrusa*, Franklin (B). *Dryopteris intermedia*, Morgan (B). *D. thelypteris* v. *pubescens*, Jennings (B). *Polystichum acrostichoides*, Delaware (BS). *Athyrium angustum*, Delaware (BS). *A. asplenioides*, Delaware (BS), Green (B), Owen (B). *Equisetum arvense*, Delaware (BS).

Juniperus virginiana v. *crebra*, Greene (B), Huntington (Hu). *Typha angustifolia*, Green (B). *T. latifolia*, Greene (B). *Sagittaria latifolia*, Henry (D). *Bromus purgans* f. *laevivaginata*, Pulaski (D), Wayne (D). *Eragrostis hypnoides*, Pulaski (D). *E. pectinacea*, Adams (D). *Hystrix patula* v. *bigeloviana*, Wayne (D). *Muhlenbergia mexicana*, Adams (D). *M. sobolifera*, Grant (D). *Sporobolus cryptandrus*, Cass (B). *Brachyelytrum erectum*, Wayne (D). *Panicum dichotomiflorum*, Adams (D). *Setaria verticillata*, Rush (D). *Cyperus strigosus*, Huntington (Hu). *Eleocharis acicularis* v. *typica*, Pulaski (D). *E. compressa*, Greene (B), Howard (B), Newton (B). *E. obtusa*, Huntington (Hu). *Carex comosa*, Huntington (Hu). *C. grayii*, Wayne (D). *C. squarrosa*, Huntington (Hu).

Acorus calamus, Huntington (Hu). *Symplocarpus foetidus,* Delaware (BS). *Arisaema atrorubens* f. *viride,* Delaware (BS), Vermillion (B). *A. a.* f. *zebrinum,* Delaware (BS). *Commelina communis,* Greene (B): *Tradescantia virginiana,* Adams (BS). *Luzula multiflora* v. *bulbosa,* Vermillion (B). *Allium candense,* Franklin (B), Henry (BS). *A. vineale,* Hamilton (B), Vermillion (B). *Polygonatum commutatum* Vermillion (B). *Smilacina racemosa* v. *cylindrata,* Henry (B). *Medeola virginiana,* Greene (B). *Trillium flexipes,* Greene (B). *T. grandiflorum,* Delaware (BS). *T. sessile* f. *luteum,* Delaware (BS), Henry (BS). *Dioscorea quaternata,* Franklin (B). *Sisyrinchium albidum,* Huntington (Hu). *S. angustifolium (S. graminoides* of Flora), Delaware (BS). *Cypripedium candidum,* Randolph (B). *Habenaria peramoena,* Greene (B). *Spiranthes cernua,* Pulaski (D).

Salix pedicellaris v. *hypoglauca,* Steuben (D). *S. rigida,* Huntington (B). *Populus heterophylla,* Clay (B), Greene (B). *Juglans nigra,* Greene (B), Rush (D). *Carya ovalis* v. *obovalis,* Huntington (B). *Quercus bicolor,* Clay (B). *Q. coccinea* v. *tuberculata,* Martin (B). *Q. muhlenbergii,* Miami (D). *Q. palustris,* Jennings (B). *Ulmus thomasi,* Rush (D). *Urtica dioica* v. *procera,* Adams (D), Wabash (B). *Laportea canadensis,* Wabash (B). *Asarum canadense,* Delaware (BS). *Rumex acetosella,* Delaware (BS). *R. verticillatus,* Huntington (Hu). *Polygonum aviculare,* Huntington (Hu). *P. buxiforme,* Putnam (B). *P. coccineum,* Pulaski (D). *P. hydropiperoides,* Clay (B), Huntington (Hu). *P. neglectum,* Greene (B). *P. .pennsylvanicum* v. *laevigatum,* Adams (D). *P. p.* v. *l.* f. *pallescens,* Huntington (B), Wabash (B). *P. persicaria,* Greene (B). *P. punctatum,* Greene (B), Wabash (B). *P. scandens,* Henry (B). *Parietaria pennsylvanica,* Rush (D)

Chenopodium ambrosioides ssp. *eu-ambrosioides* v. *typica,* Wabash (B). *Atriplex patula,* Huntington (Hu). *Amaranthus albus,* Monroe (IU). *A. graecizans,* Monroe (IU). *A. hybridus,* Adams (D), Monroe (IU). *A. spinosus,* Greene (B), Henry (D). *Acnida altissima,* Huntington (B). *Mollugo verticillata,* Clay (B). *Oxybaphus nyctogineus,* Pulaski (D). *Stellaria longifolia,* Delaware (BS). *S. media,* Delaware (BS). *Cerastium vulgatum* v. *hirsutum,* Delaware (BS). *Arenaria serpyllifolia,* Delaware (BS), Vermillion (B). *Paronychia fastigiata,* Greene (B). *Lychnis alba,* Monroe (IU). *Dianthus armeria,* Monroe (IU). *Caltha palustris,* Boone (B). *Isophyrum biternatum,* Delaware (BS). *Ranunculus abortivus,* Greene (B). Montgomery (B), Owen (B). *R. micranthus,* Franklin (B). *R. sceleratus,* Jay (BS).

Podophyllum peltatum, Delaware (BS). **P. peltatum f. deamii** Raymond, Rhodora, 50: 18. 1948. Harrison (D). Collected by Charles C. Deam. *Berberis vulgaris,* Henry (D). *Asimina triloba,* Greene (B). *Corydalis flavula,* Huntington (B, Hu). *Lepidium campestre,* Greene (B). *Lepidium virginicum* v. *typicum,* Greene (B). *Thlaspi arvense,* Delaware (BS). *Sisymbrium altissimum,* Huntington (Hu). *Brassica kaber* v. *pinnatifida,* Wells (BS). *Barbarea vulgaris* v. *arcuata,* Delaware (BS), Greene (B). *Rorippa islandica* v. *microcarpa,* Greene (B).

Nasturtium officinale, Delaware (BS). *Armoracea rusticana,* Delaware (BS). *Cardamine bulbosa,* Clinton (B). *Capsella bursa-pastoris,* Greene (B). *Descurainea sophia,* Delaware (BS). *Arabis glabra,* Henry (BS). *A. hirsuta* v. *adpressipilis,* Delaware (BS). *A. laevigata,* Adams (BS), Delaware (BS). *Hesperis matronalis,* Delaware (BS).

Sedum ternatum, Delaware (BS). *Rubus occidentalis,* Delaware (BS). *Potentilla monspeliensis,* Greene (B). *P. recta,* Delaware (BS). *Geum laciniatum* v. *trichocarpum,* Greene (B). *G. vernum,* Clinton (B). *Agrimonia parviflora,* Steuben (D). *A rostellata,* Greene (B). *Baptisia leucantha,* Greene (B). *Medicago lupulina,* Greene (B). *Melilotus alba,* Greene (B). *Trifolium hybridum,* Huntington (Hu). *T. h.* v. *elegans,* Delaware (BS). *T. pratense,* Huntington (Hu). *T. repens,* Huntington (Hu). *Robinia pseudoacaccia,* Huntington (Hu). *Lespedeza capitata* v. *velutina,* Newton (B), White (B). *Amphicarpa bracteata,* Owen (B). *Apios americana,* Greene (B), Pulaski (B). *Strophostyles liosperma,* Greene (B). *Geranium carolinianum,* Delaware (BS), Vermillion (B). *G. pusillum,* Huntington (Hu). *Oxalis europaea,* Delaware (BS). **O. e.** v. **bushii** (Small Wieg. Rhodora 27: 136. 1925.) Greene (B). Collected by R. C. Friesner. *O. e.* v. *b.* f. *subglabrata,* Greene (B). *O. e.* v. *b.* f. *vestita,* Greene (B). *O stricta,* Delaware (BS), Grant (BS). *O. violacea* v. *trichophora,* Montgomery (B). *Linum medium* v. *texanum,* Greene (B). *Polygala ambigua,* Brown (IU). *Euphorbia commutata,* Bartholomew (B), Delaware (BS).

Staphylea trifolia, Franklin (B). *Vitis palmata,* Vermillion (B). *Hibiscus trionum,* Adams (D). *Hypericum sphaerocarpum,* Greene (B). *H. tubulosum,* Harrison (W). *Viola pallens,* Howard (B). *V. striata,* Bartholomew (B). *V. triloba,* Ripley (B). *Decodon verticillatus,* Pulaski (D). *Oenothera laciniata,* Greene (B). *Myriophyllum heterophyllum,* Kosciusko (B). *Proserpinaca palustris* v. *crebra,* Pulaski (D).

Sanicula canadensis v. *typica,* Greene (B), Henry (B). *Osmorhiza claytoni,* Jennings (B). *Erigenia bulbosa,* Bartholomew (B). *Taenidia integerrima,* Adams (BS). *Thaspium barbinode,* Delaware (BS). *T. trifoliatum* v. *flavum,* Morgan (B). *Pastinaca sativa,* Delaware (BS). *Nyssa sylvatica* v. *caroliniana,* Vermillion (B). *Monotropa uniflora,* Pulaski (D). *Samolus parviflorus,* Brown (IU). *Lysimachia lanceolata,* Noble (B). *Dodecatheon meadia,* Huntington, (Hu), Ripley (B). *Fraxinus americana,* Greene (B). *F. biltmoreana,* Clay (B), Greene (B). *F. lanceolata,* Greene (B). *F. quadrangulata,* Rush (D). *F. tomentosa,* Clay (B). *Gentiana andrewsii,* Clay (B). *G. procera,* Carroll (B).

Apocynum cannabinum v. *glaberrimum,* Greene (B), Morgan (B). *Asclepias incarnata,* Brown (IU). *A sullivantii,* Greene (B). *A syriaca,* Greene (B). *A. tuberosa* ssp. *interior,* Greene (B). *Cuscuta campestris,* Henry (B, DP). Jennings (B), Wabash (B, DP). *C. glomerata,* Greene (B, DP). *C. gronovii,* Huntington (Hu, B), Owen (B). *Convolvulus sepium* v. *americanus,* Greene (B). *Phlox glaberrima,* Greene (B). *Collomia linearis,* Lake (D). *Hydrophyllum appendiculatum,* Rush (D).

Phacelia purshii, Delaware (BS). *Cynoglossum virginianum,* Morgan (B). *Myosotis macrosperma,* Wells (BS). *M. scorpioides,* Wabash (B). *Mertensia virginica,* Delaware (BS). *Lithospermum arvense,* Bartholomew (B). *Verbent hastata,* Henry (D,B). *X. V. rydbergii,* Pulaski (B) *V. stricta,* Pulaski (B). *V. urticaefolia* v. *leiocarpa,* Huntington (B), Owen (B). *Teucrium canadense* v. *virginicum,* Greene (B), Steuben (D). *T. occidentale* v. *boreale,* Greene (B). *Scutellaria lateriflora,* Greene (B), Pulaski (D). *S. parvula* v. *leonardi,* Greene (B). *Agastache nepetoides,* Grant (D). *Glecoma hederacea* v. *parviflora,* Delaware (BS). *Physostegia speciosa,* Wabash (B). *Lamium purpureum,* Monroe (IU). *Stachys tenuifolia* v. *hispida,* Greene (B). *Monarda fistulosa* v. *mollis,* Greene (B). *Pycnanthemum incanum,* Greene (B). *P. flexuosum,* Henry (B). *P. virginianum,* Pulaski (D). *Lycopus americanus,* Greene (B). *L. rubellus,* Greene (B). *L. uniflorus,* Clay (B). *Perilla frutescens* v. *crispa,* Wabash. (B). *Lycium halimifolium,* Monroe (IU). *Physalis heterophylla,* Franklin (B), Owen (B). *Solanum nigrum,* Pulaski (D). *Datura stramonium,* Greene (B). *Collinsia verna,* Delaware (BS), Ripley (B). *Chelone obliqua* v. *speciosa,* Greene (B). **Penstemon gracilis** Nutt. Rhodora 49:256. 1947. Lake (G). Collected by Edwin D. Hull. *Mimulus ringens,* Greene (B). *Leucospora multifida,* Henry (B). *Gerardia purpurea,* Carroll (B). *G. tenuifolia* v. *typica,* Clay (B).

Plantago lanceolata, Delaware (B), Greene (B). *P. rugelii,* De Kalb (D). *Houstonia longifolia,* Delaware (BS). *Diodia teres* v. *setifolia,* Monroe (IU). *Galium tinctorium (G. trifidum* ssp. *tinctorium),* Brown (IU). *Triosteum aurantiacum,* Clinton (B). *Lonicera dioica,* Scott (B). *Valeriana pauciflora,* Delaware (BS). *Viburnum dentatum* v. *deamii,* Greene (B). *Sicyos augulatus,* Morgan (B). *Campanula rapunculoides,* Lake (G). Rhodora 47:404. *C. uliginosa,* White (B). *Lobelia spicata* v. *leptostachya,* Greene (B).

Vernonia fasciculata, Cass (B), Pulaski (B). *Eupatorium altissimum,* Miami (D). *E. maculatum,* Pulaski (D). *E. purpureum,* Pulaski (D). *E. rugosum,* Pulaski (D). *E. serotinum,* Owen (B). *Liatris spicata,* Greene (B). *Solidago canadensis* v. *gilvocanescens,* Huntington (B). *S. latifolia,* Owen (B). *S. rugosa* v. *typica,* Henry (B). *Aster cordifolius,* Cass (B). *A ericoides,* Pulaski (D). *A. interior,* Clay (B), Owen (B), Wabash (B). *A. lucidulus,* Carroll (B). *A. novae-angliae,* Adams (D). *A. praealtus,* Lake (B). *A. p.* v. *angustior,* Huntington (B). *Erigeron annus,* Franklin (B), Greene (B). *E. strigosus,* Greene (B). *Antennaria fallax,* Delaware (BS). *A neglecta,* Marion (B). *A. neodioica,* Delaware (BS). *Silphium laciniatum* v. *robinsonii,* Tipton (B). *S. perfoliatum,* Wabash, (B). **S. terebinthinaceum** v. **pinnatifidum** (Ell.) Gray, Gray Man. 7 ed. p. 825. Pulaski (B, D). Collected by Charles C. Deam and R. C. Friesner. *Ambrosia elatior,* Greene (B), Huntington (B). *Rudbeckia deamii,* Greene (B). *R. hirta,* Delaware (BS). *R. laciniata,* Henry (D). *R. sullivantii,* Greene (B).

Helianthus annuus, Monroe (IU). *H. divaricatus,* Cass (B), Monroe (IU). *H. giganteus,* Marion (B). *H. hirsutus,* Pulaski (D). *H. stru-*

mosus, Huntington (B). *Bidens discoidea,* Pulaski (D). *Galinsoga ciliata,* Greene (B). *Helenium autumnale* v. *parviflorum,* Huntington (B), Wabash (B). *Anthemis cotula,* Brown (IU), Greene (B). *Matricaria matricarioides,* Noble (B), Ripley (IU). *Chrysanthemum leucanthemum* v. *pinnatifidum,* Delaware (BS). *Senecio plattensis,* Montgomery (B). *Arctium minus,* Clay (B), Huntington (Hu). *Cirsium discolor,* Cass (B). *Tragopogon porrifolius,* Delaware (BS), Greene (B). *T. pratensis,* Delaware (BS). *Taraxacum palustre* v. *vulgare,* Greene (B). *Lactuca canadensis* v. *obovata,* Huntington (B). *L. c.* v. *typica,* Greene (B). *L. saligna,* Greene (B), Monroe (IU).

ADDITIONAL SPECIES ADDED TO THE DEAM HERBARIUM

The following species previously reported in other herbaria have been added to the Deam herbarium since the last report.

Juniperus virginiana v. *crebra,* Miami. *Hordeum jubatum,* De Kalb. *Setaria viridis,* Rush. *Sorghastrum nutans,* Henry. *Lilium michiganense,* Wayne. *Quercus alba,* Pulaski. *Amaranthus spinosus,* Wells, *Caulophyllum thalictroides,* Rush. *Penthorum sedioides,* Pulaski. *Agrimonia parviflora,* Henry. *Epilobium coloratum,* Pulaski. *Desmodium sessilifolium,* Pulaski. *Thaspium barbinode,* Wayne. *Asclepias sullivantii,* Pulaski. *Viburnum dentatum* v. *deamii,* Henry. *Vernonia altissima,* Henry. *V. missurica,* Pulaski. *Eupatorium fistulosum,* Henry. *E. perfoliatum,* Henry. *Solidago nemoralis* v. *decemflora,* Pulaski. *Rudbeckia triloba,* Jefferson. *Erechtites hieracifolia,* Pulaski. *Cirsium muticum,* Henry.

DELETIONS

The following specimen reported in Records IV should be deleted: *Rhamnus lanceolata,* Jennings (B).

State Flora Committee:

Charles C. Deam, *Chairman*
T. G. Yuncker
Ray C. Friesner, *Secretary.*

CHEMISTRY

Chairman: E. St. Clair Gantz, Purdue University

William G. Kessel, Indiana State Teachers College, was elected chairman for 1949.

ABSTRACTS

Should Inorganic Chemistry be Restored to the Undergraduate Curriculum? Charles L. Rulfs, Herbert C. Brown, E. St. Clair Gantz, Purdue University.—In effect, inorganic chemistry is no longer being taught in the usual undergraduate curriculum. The time and attention which were once devoted to the subject in the first and second year courses in chemistry are now primarily devoted to physical chemical topics. As a result, the average chemistry major is ignorant of any but the most rudimentary facts of inorganic chemistry and is greatly handicapped as a result. Because of the large proportion of non-chemistry majors in the present General Chemistry and Qualitative Analysis courses, it is probably undesirable to attempt to shift the present emphasis on chemical theory back to descriptive inorganic chemistry. Instead, it is believed that the present deficiency can best be remedied by introducing in the junior or senior year a new course in inorganic chemistry. Such a course, required of all chemistry majors, would acquaint the students with the subject matter of inorganic chemistry much as the present organic course presents the subject matter of organic chemistry. Although others may prefer a different solution, some means must soon be found to remedy the present glaring deficiency in the training of chemistry majors.

More About the Composition of Turquoise, Frank B. Wade, Head, Dept. of Chemistry, Shortridge High School, Indianapolis, Ind.—Further study of turquoise shows that it contains Carbon. We had previously shown that it contained nitrogen. We then suspected that the color was due to $Cu(NH_3)_4^{++}$ ion. We now suspect that the colorant may be $CH_3NH_2Cu^{++}$ ion since combustion tests show that the amount of carbon agrees well with the amount of nitrogen if $CH_3\ NH_2\ Cu^{++}$ ion is the colorant.

Table of analyses made by the Chem IV class at Shortridge High School under the direction of Walter C. Geisler follows:

Sample	CO_2	(calc.) Carbon	N equiv. (calc.)	NH_3 (calc.)	NH_3 (found)
1	.365	.099	.115	.139	.16
2	.241	.065	.075	.091	.10
3	.237	.064	.074	.089	.10
4	.296	.077	.089	.108	.12
5	.312	.085	.096	.119	.13

Determination of Fluorine in Waters, I. A Rapid Direct Method, II. A Rapid Distillation Method. W. E. THRUN, Valparaiso, University.—A dilute solution of the aluminum lake of Eriochromecyanine buffered at pH 5.4-5.6 is the reagent used with 5 to 10 ml. samples of water. The fluoride ion destroys the color. Comparisons with standards are made 10-15 minutes later.

The distillation is performed over sulfuric acid with a 100 ml. sample plus 10 ml. of distilled water until 90 ml. have been collected. The distillate is cooled, buffered to pH 5.4-5.6, made up to 100 ml., and the fluorine determined as above. The distillation is performed by creating a high turbulence with air and a high temperature.

Since the agreement between the results by the direct method and those obtained on the distillate is excellent and since the aluminum ion deepens the color and the silicate ion destroys it, a very reasonable assumption should be that the alumina and silicate in natural waters are tied up with each other and that the fluorine exists as ions.

The Separation of Isomers of Nickel (II) Complexes by Chromatographic Adsorption. E. ST. CLAIR GANTZ and BENEDICT L. VONDRA, Purdue University.—Nickel complexes of glycine benzeneazo-β naphthol, methylglyoxime, salicylaldoxime, salicylaldehyde, benzoylacetone, and salicylaldimine were prepared. The complex with methylglyoxime is known to exist in isomeric forms. This information is lacking with regard to the other compounds. It was hoped that an adsorbent or adsorbents and eluting reagents might be discovered by which isomeric forms could be isolated. No resolutions were obtained using a variety of adsorbents including alumina, magnesium oxide, silica gel, barium sulfate, calcium sulfate, and talc. A large number of solvents were also used in an effort to obtain a separation of isomers on the various columns studied.

Studies of Lithium Hydride[2]

D. W. PEARCE,[1] R. E. BURNS,[1] and E. ST. CLAIR GANTZ,
Purdue University

Introduction

The negative character of the hydrogen in lithium hydride was first postulated by Lewis (1) and later by Nernst (2). Their predictions were substantiated by Moers (3) and Peter (4) who were able to show that, in the electrolysis of lithium hydride, hydrogen is liberated at the anode. The fact that the negative hydrogen present in lithium hydride and other salt-like hydrides is a powerful reducing agent is well known (5). However, very little specific information relative to the reducing properties of lithium hydride is available in the literature. These investigations were undertaken in the hope that additional information concerning the behavior of lithium hydride toward inorganic compounds, particularly those of elements of the transition groups might be gained. It was also desired to find a reaction medium in which lithium hydride is soluble and stable and to develop the necessary techniques for studying reactions with lithium hydride in such a medium.

Two different types of reactions were studied. In the first case, solid-solid reactions involving mixtures of lithium hydride with various chlorides and oxides were investigated. It was found that lithium hydride is soluble without decomposition in the fused lithium chloride-potassium chloride eutectic (40 mole per cent potassium chloride) which melts at 350°C. The second series of reactions studied was between suspensions of certain oxides in this melt and lithium hydride dissolved in the melt.

Experimental

The lithium hydride used in these investigations was obtained from the Fairmount Chemical Company of Newark, New Jersey. For use in these studies it was necessary to grind the hydride to a fineness of about 100 mesh. A solenoid-operated vacuum grinder was used for this purpose to prevent the reaction of the hydride with moisture in the air during the grinding process.

All of the reactions studied were performed in an apparatus similar to that shown in Figure 1. The reaction vessel consisted of a stainless steel crucible. A large thick-walled test tube heated by an electric muffle formed the reaction vessel. The type of manometer used depended

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[1] Now at Hanford Chemical Works, Richland, Washington.

[2] This paper contains material from thesis of R. E. Burns presented to faculty of Purdue University in partial fulfillment of requirements of Ph.D. Feb. 1948.

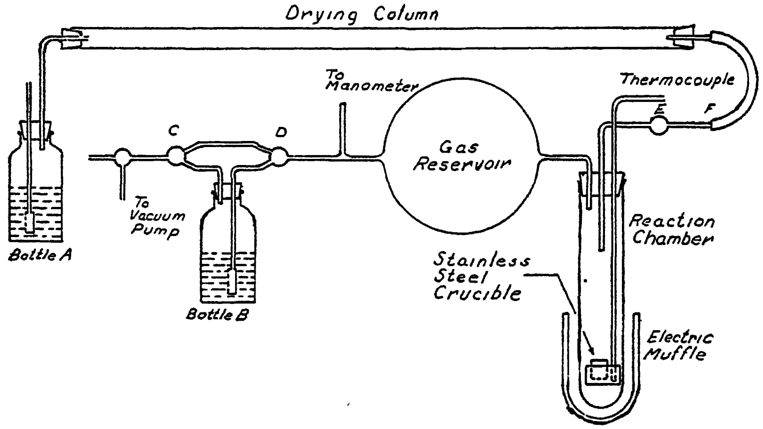

Figure 1 Apparatus for Studying Reactions

upon the reaction being studied. A Wegner distillation pump capable of reducing the pressure to 0.01 mm. Hg. was used to evacuate the apparatus. Gases admitted to the apparatus passed through Bottle (A), containing a strong potassium hydroxide solution, and the drying column which was packed with Drierite. Carbon dioxide and water were thus removed from the admitted gases. Bottle (B) contained a standardized sodium hydroxide solution and the two three-way stopcocks (C) and (D) provided a means whereby the gaseous products generated during a reaction could be pumped through the standard base solution.

(I) *Solid-Solid Reactions of Lithium Hydride with Alkali Chlorides.*—A series of four reactions was studied in which mixtures of solid lithium hydride with, successively, the solid chlorides of sodium, potassium, rubidium, and cesium were heated under reduced pressure. For these reactions a Zimmerli manometer was attached to the apparatus to permit the determination of small departures from zero pressure. The reactions were all performed in essentially the same manner. A small, known quantity of ground lithium hydride was placed in the stainless steel crucible and heated, under vacuum, to a temperature of about 550°C. for one-half hour to remove any traces of moisture. When cooled, a weighed quantity of the alkali chloride was added and mixed intimately with the lithium hydride. The alkali chlorides had been previously ground and then dried at temperatures slightly below their melting points. The mixture was then heated to 300°C. under vacuum (continuous pumping). At that temperature the system was closed to permit any gas generated by the reaction to be retained in the apparatus.

In each case, at temperatures around 500°C. there occurred a sudden increase in pressure and a mirror-like deposit formed on the walls of the reaction chamber above the heated zone. The reaction usually continued for about thirty minutes. When the apparatus had cooled to room temperature, the pressure was noted and the amount of gas produced was calculated by use of the gas law.

Air was then admitted to the apparatus through Bottle (A). Bottle (B) contained a standard sodium hydroxide solution. The gases in the apparatus were then pumped through Bottle (B) and the resulting solution was titrated with standard hydrochloric acid solution.

The distilled material in the mirror-like deposit and the residue remaining in the crucible were examined separately for lithium and the other alkali metal concerned by standard analytical procedures. The data obtained in these experiments are shown in Table 1. It is to be noted that in no case was any hydrogen chloride produced. Also it is of interest that reduction of the alkali metal chloride to the metal is nearly complete in each case and the quantity of gas produced corresponds roughly to one-half mole of hydrogen per mole of alkali chloride reduced. In view of these observations it was concluded that the reactions were probably of the type

$$2\,LiH + 2\,MCl \rightarrow 2\,LiCl + 2\,\overline{M} + H_2. \qquad (A)$$

These reactions were repeated using metallic lithium in place of the lithium hydride. The alkali metal chlorides were reduced to the metals in these reactions in the same manner and at about the same temperature as when lithium hydride was used. Consequently, one cannot be certain whether a reaction mechanism as illustrated by the following equations is responsible for the reductions observed when lithium hydride is used rather than that represented by Equation (A).

$$2\,LiH \rightarrow 2\,Li + \overline{H_2}$$

$$2\,Li + 2\,MCl \rightarrow 2\,\overline{M} + LiCl \qquad (B)$$

The same relative quantity of gas would be produced in either case. However, the pressures attained in the reactions involving lithium hydride ranged from 16 to 26 mm. Hg. while the decomposition pressure of lithium hydride is given as 0.07 mm. Hg. at 500°C. Hence, for the reaction as represented by (B) to continue, the lithium hydride would have to decompose against a pressure of hydrogen much in excess of its decomposition pressure at the reaction temperature.

(II) *Solid-Solid Reactions of Lithium Hydride With Oxides of Groups IV and V.*—These reactions were performed in essentially the same manner as those involving the alkali halides except that the preheating of the lithium hydride to remove moisture was not done and the gases evolved were not checked for the presence of acidic constituents. No products distilled out of the reaction vessel in these reactions. Pressures and temperatures were noted and the quantity of gas evolved was calculated, although no coordination between the quantity of gas evolved and the degree of reduction attained was found. Since the decomposition pressure of lithium hydride is about 15 mm. Hg. at the temperatures reached in these experiments (ca. 600°C.) it is

TABLE I. Reaction of Lithium Hydride with Alkali Chlorides.

Alkali Chloride	m. Moles LiH	m. Moles Alkali Chloride	Mole Ratio LiH/MCl	m. Moles Gas Per m. Mole MCl	m. eq. HCl formed	MCl Left in Residue	Temp. of Initial React.	Max. Temp
NaCl	9.72	1.22	7.96	0.50	0	absent	500	520
KCl	9.08	1.13	8.01	0.51	0	absent	490	517
RbCl	13.0	1.58	8.22	0.53	0	ca. 5 mg. present	472	530
CsCl	6.95	0.881	7.88	0.58	0	trace	480	530

TABLE 2. Reactions of Lithium Hydride with Group IV and Group V Oxides.

Oxide	m. Moles Oxide	LiH m. Moles	Mole Ratio LiH Oxide	Max. Temp. °C.	m. Moles Gas Per m. Mole Oxide	Color of Product	Possible Formula Product
ThO_2	1.825	7.86	4.31	600	0.53	White	ThO_2
ZrO_2	1.62	6.71	4.13	610	0.70	Black	Zr, (ZrO, Zr_2O_3)
TiO_2	1.99	12.32	6.2	600	0.715	Black	Ti_2O_3
SiO_2	2.675	10.56	3.95	600	1.33	Black	Si
GeO_2	1.19	5.97	5.02	610	1.79	Black	GeO
Cb_2O_5	0.469	3.95	8.43	605	3.33	Black	Cb_2O_3, CbO_2

entirely possible that the decomposition of the hydride produced the major portion of the gas evolved. The data obtained for the solid-solid reactions between lithium hydride and thorium dioxide, zirconium dioxide, titanium dioxide, silicon dioxide, germanium dioxide and columbium pentoxide are given in Table 2.

The determination of the composition of the products of these reactions was difficult because of the instability of these elements in their lower oxidation states. The reaction product was, in each case, treated with water to remove the excess lithium hydride and any lithium oxide or metallic lithium formed in the reaction. The solutions were filtered and an attempt was made in each case to identify the residue by solubility tests. The probable formulas of the reduction products are given in Table 2.

(III) *Reactions of Lithium Hydride in a Lithium Chloride—Potassium Chloride Melt.*—In performing these reactions the apparatus shown in Figure 1 was used. An open J-tube manometer was used for pressure measurement since these reactions were studied under an atmosphere of helium at near atmospheric pressure. The following procedure was followed for all of the reactions studied. About one gram of lithium chloride was placed in a weighed stainless steel crucible and heated for one hour under vacuum (continuous pumping) and at a temperature of about 550°C. When cool, the crucible was weighed and the proper amount of potassium chloride previously dried by heating, was added to produce the eutectic. This mixture was heated under vacuum to a temperature of 300°C. Helium was then admitted through Bottle (B) to bring the apparatus to atmospheric pressure. Heating was continued until the mixture had fused completely. When again cool, a weighed amount of ground lithium hydride was added and the mixture was heated until fusion occured and the lithium hydride dissolved in the melt following the same procedure as when the potassium chloride was added.

When the apparatus was again cool, a weighed amount of the compound to be reacted with the lithium hydride was added. The mixture was then heated under vacuum to a temperature of 300°C. Helium was then admitted through Bottle (B) and the heating was continued. At some definite temperature, usually 345°C., the apparatus was allowed to come to atmospheric pressure. The system was then closed off and heating was continued until fusion occurred. In each case studied, a rapid reaction occurred immediately after fusion of the mixture. Heating was continued until the reaction was complete as indicated by a constant pressure. As the apparatus cooled, the pressure in the apparatus was noted when the temperature reached that at which the system was closed during heating. The pressure was again noted when the apparatus had cooled to room temperature. The atmospheric pressure was also noted. From the pressure and temperature data taken, the quantity of gas generated in the reaction could be calculated roughly. The gases in the apparatus were pumped through a standard sodium hydroxide solution in Bottle (B) and the resulting solution was titrated with standard hydrochloric acid solution.

TABLE 3. Reactions of Ta_2O_5, Cb_2O_5, V_2O_5, and Eu_2O_5 in a KCl-LiCl Melt.

Oxide	Run	m. Moles Oxide	m. Moles LiH	Mole Ratio $\frac{\text{LiH}}{\text{Oxide}}$	m. Moles Gas / m. Moles Compound	m. Moles Acidic Gas Formed	mg. Product	mg. Starting Material	Possible Formula Product
Ta_2O_5	A	0.786	12.64	16.1	1.86	0	345.0	348.2	TaO_2
Ta_2O_5	B	0.5797	9.13	15.5	1.97	0	264.6	256.8	$TaO_2 \bullet H_2O$
Cb_2O_5	A	1.364	21.8	16.0	2.52	0	334.0	363	Cb_2O_3
Cb_2O_5	B	.7304	11.41	15.6			147.7	194.4	Cb_2O_3
Cb_2O_5	C	.4419	6.98	15.8	2.50	0	106.0	117.6	Cb_2O_3
V_2O_5	A	1.902	24.7	13.0	3.86	0	215.2	346	VO
Eu_2O_3	B	0.435	6.4	14.9	1.5	0	133.3	152.9	Eu_2SO_4
Eu_2O_3	A	0.430	6.8	15.7	1.5	0	53.5	151.7	Eu_2SO_4

Treatment of the residues differed according to the reaction being studied. Table 3 presents the data obtained in the study of the reaction of lithium hydride with tantalum pentoxide, columbium pentoxide, vanadium pentoxide, and europium trioxide.

Summary

Lithium hydride reacts with sodium chloride, potassium chloride, rubidium chloride, and cesium chloride under reduced pressure and at temperatures around 500°C. In each case a gas (probably hydrogen) is evolved and the alkali metal other than lithium is distilled from the hot zone to the cooler parts of the reaction chamber. The results obtained indicate that the reaction is probably of the type

$$LiH + MCl \rightarrow LiCl + \overline{M} + H_2.$$

Many oxides of Group IV and Group V elements react with lithium hydride under reduced pressure and at temperatures around 500°C. The product of the reduction may be the element or oxides of the element in lower oxidation states. The experiments performed indicate that the following reductions occur under these conditions.

Thorium dioxide is not reduced.
Zirconium dioxide is reduced to the metallic state.
Titanium dioxide is reduced to the tervalent state.
Silicon dioxide is reduced to amorphous silicon.
Germanium dioxide is reduced at least to the bivalent state and perhaps to the metal.
Columbium pentoxide is reduced, possibly to the tervalent state.

The lithium chloride-potassium chloride eutectic, at its melting point, will dissolve lithium hydride. The resulting solution may be used as a reaction medium for the study of reactions of lithium hydride with solids not soluble in the eutectic. The reactions of the pentoxides of tantalum, columbium, and vanadium with lithium hydride in the eutectic were studied.

The identification of the products obtained in these reactions was difficult due to the instability of these elements in their lower oxidation states. The evidence obtained indicates that tantalum is reduced at least to the tervalent state and that vanadium is reduced to the bivalent state. The identification of these oxidation states was not rigorous and the results obtained are indicative only.

Europic oxide reacts with lithium hyride in a potassium chloride-lithium chloride melt. The europium may be recovered as europous sulfate by disintegrating the product obtained with dilute sulfuric acid. Quantitative recovery was not achieved.

This study is being continued in this laboratory.

References

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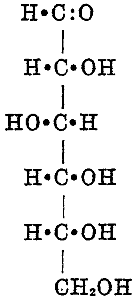
The Validity of the Emil Fischer Concept

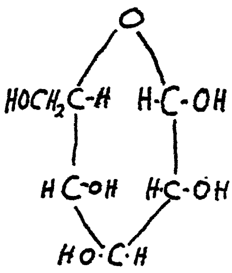
Ed F. Degering, Purdue University

The author has previously shown that (1) it is possible to make a straightforward transition from the aldehyde formula of a sugar to the pyranose or furanose formula and thus present a spatial concept of the molecule, and that (2) the configurational concept proposed by Emil Fischer visualizes the hydrogen atom and the hydroxyl group of an asymmetric grouping as *lying above the plane of the paper*, with the two other groups below the plane of the paper.

These two concepts enable one to make the transition from an aldehyde formula to a pyranose formula with ease, as indicated by:



$$\begin{array}{c} H\cdot C:O \\ | \\ H\cdot C\cdot OH \\ | \\ HO\cdot C\cdot H \\ | \\ H\cdot C\cdot OH \\ | \\ H\cdot C\cdot OH \\ | \\ CH_2OH \end{array}$$

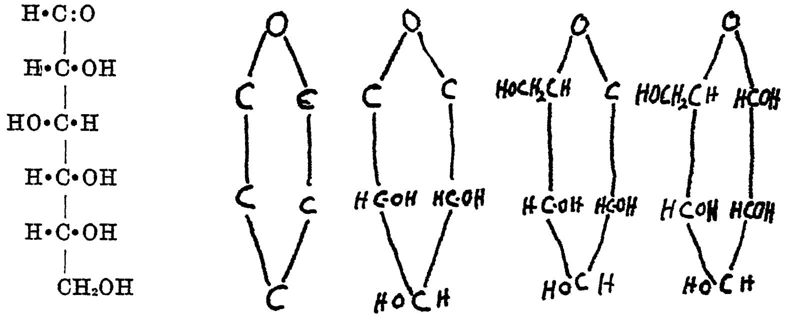


The open chain formula on the left, by ring formation and orientation so that the hetero atom is placed at the top and *the corresponding groups read left to right,* the same as in the aldehyde formula, becomes the pyranose formula shown at right.

D+-glucose, aldehyde formula

α-D+-glucopyranose

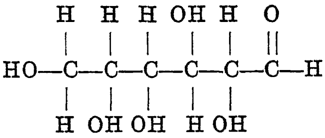
The transition from an open chain aldose sugar formula to a pyranose formula, consists of (1) writing the open chain aldose formula, (2) writing a pyranose ring, with the oxygen atom oriented at the top and the carbon atoms numbered clockwise, (3) filling in the corresponding asymmetric groups so that they read *left to right in both formulas,* (4) placing the terminal HO•CH₂-group to the left with the H-atom to the right in the *D*-series or *vise versa* in the *L*-series, and (5) filling in the H- and OH-groups on carbon atom grouping No. 1 so as to give the *alpha-* or *beta-*form as desired. Diagramatically, the steps are:



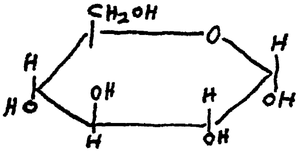
α-*D*-glucopyranose,
by Degering

Step No. 1 Step No. 2 Step No. 3 Step No. 4 Step No. 5

Even the beginning student in organic chemistry makes the transition with ease, whereas graduate students encounter extreme difficulty in making the transition from the open chain formula of α-D^{+}-glucose, for example, to the Haworth formula which is indicated below. The transition to the Haworth formula would be comparatively simple if the conventional method of writing the formula of D-glucose, for example, was as follows:



$$\begin{array}{lcccccc} & \mathrm{H} & \mathrm{H} & \mathrm{H} & \mathrm{OH} & \mathrm{H} & \mathrm{O} \\ & | & | & | & | & | & \| \\ \mathrm{HO}- & \mathrm{C}- & \mathrm{C}- & \mathrm{C}- & \mathrm{C}- & \mathrm{C}- & \mathrm{C}-\mathrm{H} \\ & | & | & | & | & | & \\ & \mathrm{H} & \mathrm{OH} & \mathrm{OH} & \mathrm{H} & \mathrm{OH} & \end{array}$$



α-*D*-glucopyranose,
by Haworth

In view of the fact, however, that the formulas of the open chain sugars are written vertically with the aldehyde group at the top, the transition to the Haworth formula becomes difficult. One should not discount the significant contribution which was made to the chemistry of the carbohydrates by the introduction of the ring or closed chain formulas by Haworth and Peat[3], nor should one be a slave to a concept that does not follow the accepted orientation of heterocyclic systems[5] nor permit of ready transition from the open chain system with which the student is most familiar to the closed chain, ring, or pyranose system.

At the same time, moreover, one is able to visualize the spatial arrangement of the atoms in the pyranose formula in that all of the groups lying to the *right* of a carbon atom are *below* the plane of the paper, whereas those lying to the *left* of the same carbon atom are *above* the plane of the paper. This may be indicated by making the proper lines heavy so as to give a perspective as well as a projection representation. This relative position of the H- and OH-groups with respect to the plane of the molecule may be confirmed readily by the construction of a tinker-toy model of the sugar concerned.

This concept seems the more significant now that Werner Kuhn has produced mathematical proof to vindicate the correctness of the Emil Fischer guess and thus increase the probability that the representation of α-D^{+}-glucopyranose as shown above is correct.

Actually, Kuhn established the absolute configuration of D—-lactic acid, but by so doing he likewise established the absolute configuration of the simple sugars and all closely related compounds.

This contribution is so significant to the organic chemist that a few paragraphs, as translated by the author, are taken from theoretical dessertation by Werner Kuhn as it appeared in the Zeitschrift fur physikalische chemie in 1935, where it has since remained buried[4].

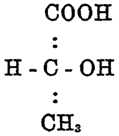
"A start for the theoretical calculation of the absolute configuration of lactic acid is made by determining by means of a simplified model, the sign of rotation of methyl ethyl carbinol, the steric relation of which to lactic acid is chemically defined.

"In the simplified model the methyl group, the active carbon atom, and the ethyl group are each represented by an isotropic resonator, whereby the charge of the ethyl group is assumed to be larger than either charge in the centers of gravity of the methyl group or of the active carbon atom. The reciprocal action of resonance occurring in these parts of the molecule is accurately calculated. For the alcoholic hydroxyl group we take respectively an isotropic and an anisotropic resonator of different directions of vibration as a starting point.

"For the calculation of the reciprocal action, the peripheral one caused by Van der Waal forces is neglected and consideration given to the reciprocal action due to direct chemical linkage.

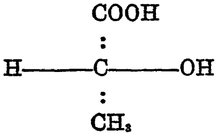
"If at first the optical vibration localized at the OH-absorption band of highest wave length is assumed to be anisotropic, one arrives at an optical activity of the second order. If the hydroxyl group is, however assumed to be isotropic, the rotation disappears in this order.

"By virtue of the Kerr-effect and the dispersion of light as observed on hydroxyl compounds, it is probable that in the carbonhydroxyl group the hydroxyl absorption band of highest wave length vibrates in the plane defined by the carbon, oxygen, and hydrogen. The result in this case is that the D—lactic acid, which according to Emil Fischer is wherein the substituents connected by the *dotted line should be pictured behind the plane o fthe drawing.*



$$\begin{array}{c} COOH \\ \vdots \\ H-C-OH \\ \vdots \\ CH_3 \end{array}$$

Formula I



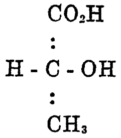
$$\begin{array}{c} COOH \\ \vdots \\ H\text{———}C\text{———}OH \\ \vdots \\ CH_3 \end{array}$$

Formula II

"It will be shown that vibrations which correspond to optical absorption bands of molecules should be considered anisotropic for theoretical as well as experimental reasons. Experimentally this is particularly evidenced by the Weigert-effect as observed on dye stuff molecules.

"Generally the optical vibrations of the absorption band of highest wave length of any given molecule takes place in that direction in which the polarizability (which is measured by the Kerr-effect and light dispersion) is at a maximum. From the Kerr-effect one can therefore conclude with good probability the direction of vibration which is characteristic for the absorption bands of highest wave length of the molecule."

Kuhn then proceeds to convince his reader by a thirty three page discussion, which is loaded with seven pages of mathematics. When one has traversed this long and weary way with Kuhn, he is convinced that Emil Fischer guessed right and the absolute configuration of D—-lactic acid is that shown at the right, in which the carbon atom at the asymmetric center lies in the plane of the paper, whereas the H- and OH-groups lie in front of the plane and the CO_2H- and CH_3-groups lie behind the plane of the page.



$$\begin{array}{c} CO_2H \\ : \\ H - C - OH \\ : \\ CH_3 \end{array}$$

D—-Lactic Acid

Having accepted the absolute configuration of lactic acid as that postulated by Emil Fischer, one is at once in a position to accept the absolute configuration of D$^+$-glucose as represented by the α-D$^+$-glucopyranose formulation at the outset of this article.

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The Structure of the Stereoisomeric Trithianes[1]

E. CAPAIGNE and WALTER M. BUDDE[2], Indiana University

When acetaldehyde is treated with hydrogen sulfide and hydrogen chloride, trithioacetaldehyde is formed, and originally (1) three different isomers; α, m.p. 101°; β; m.p. 125-6°, and γ; m.p. 81°; were isolated. It was possible to convert α into β by heating with iodine or acetyl chloride. Since the trithiane ring was assumed to be planar, only two isomers, cis-cis (I) and cis-trans (II) should exist. Suyver (2) demonstrated that a eutectic mixture of 60% α and 40% β isomer melts sharply at 75-76° and it was generally conceded that this is the explanation of the γ-isomer. It is still reported in the handbooks, however, and crops up as justification for different structures of the trithiane ring. In 1947, Schonberg and Barakat (3), disturbed by the ready interchange of α to β forms in a cylic system in which tautomerism is presumably impossible, proposed the following theory:

"The three carbon atoms and the three sulfur atoms in 1, 3, 5-trithiane molecules do not lie in one plane, but may be regarded as 'boat' and 'chair' structures, the interconversion then being readily explained. According to this explanation, the α- and β-forms of trithioacetaldehyde, for example, are either both cis- or both trans-forms; the isomeric change is due to a change of 'boat' into 'chair' structures, or vice versa. This new theory demands a greater number of isomers than have, so far, been isolated, but it is not thereby necessarily invalidated, for some isomers (γ-forms) have occasionally been described, which have been attributed *inter alia* to polymorphism or the occurrence of eutectic mixtures.

"In harmony with the new theory is the fact that the molecule of trithioformaldehyde in benzene solution and in the crystal contains not a planar but a puckered six-membered ring (4)."

Schonberg attributes the stability of the "boat" and "chair" forms to resonance.

Hinsberg (5) claimed to have isolated two forms of s-trithiane, but Fromm and Soffner (6) repeated the work and claimed that Hinsberg's second compound was actually a cyclic methylene sulfur compound, $(CH_2S)x$, where x was greater than 3. In 1929, the planar configuration of the s-trithiane ring was regarded as certain after Bell and Bennett (7) were able to separate all of the isomeric di- and tri-sulfoxides which would theoretically exist for a planar trimethylene trisulfide ring. Oxidation of s-trithiane with hydrogen peroxide in acetone yielded only one monoxide, A. Further oxidation with the calculated amount of hydrogen peroxide in acetic acid gave two disulfoxides, B and C, which could be separated by fractional crystallization from water. Since these oxides decompose at high temperatures without melting, their *non*-identity was demonstrated by their crystalline properties and solubility. Compound C, upon further oxidation yielded only one trisulfoxide, E. The

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[1] Abstracted from a thesis submitted by Walter M. Budde to the faculty of Indiana University in partial fulfillment of the requirements for the degree, Master of Arts, in the Department of Chemistry, June, 1947.

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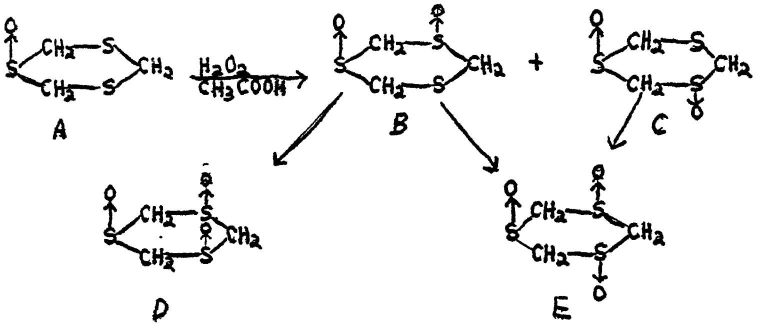
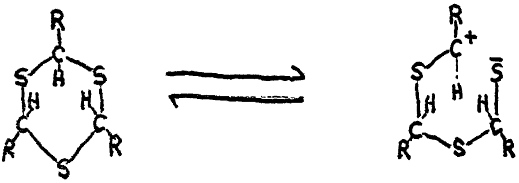


trans-configuration was therefore assigned to C, and *cis-trans* to E. This agrees with their solubilities and stabilities. Compound B upon further oxidation yielded two trisulfoxides, which were separated by fractional crystallization. One of these was identical with E, and the other, D, was assigned the *cis-cis* configuration. This would indicate that B has the *cis*-configuration.

It would seem that Schonberg's principle objection to *cis-cis* and *cis*-trans forms, the ready interconversion of α to β, could be explained by an actual tautomerism:



This is supported by some evidence obtained by Worner (8) and by our group.

Worner (8) studied isomers of the trithiobenzaldehyde series, and carefully developed methods of separating these isomers. In no case did he find more than two isomers formed in thirty different substituted benzaldehydes used. He did find that substituents exerted an influence on the products formed. Thus with certain substituents, both α and β forms could be isolated, while in other cases only one form was obtained. In some cases no trimer could be isolated. Results can be illustrated by a table.

TABLE I. Influence of Substituents on Formation of Thiobenzaldehyde Trimers.

Substituents	No. of Trimers Formed	Substituents	No. of Trimers Formed
none	2	2, 5—di—CH_3O—	2
4—CH_3O—	2	4—iso—C_3H_7	2
2—CH_3O	2	3—CH_3—	2
2—iso—C_4H_9O—	2	4—CH_3—	2
3, 4—di—CH_3O—	2	2—Br—	2
3, 4—CH_2O_2=	2	4—Br—	2
3—CH_3O—4—OH—	1	2, 4, 6—tri CH_3— (not checked carefully for 2 forms) (9)	1
2—HO—	1	3—NO_2—4—CH_3O	1
3—HO—	1	3—NO_2—4—iso—C_3H_7	1
4—HO—	1	3, 5—di NO_2—4—CH_3O—	1
2—C_6H_5COO—	1	2—CH_3—4—OH—5—iso—C_3H_7—	1 (a)
3—C_6H_5COO—	1	2—NO_2— (linear polymer)	0
3—CH_3O—	1 (?)	3—NO_2—	0 (ditto)
4—C_6H_5COO—	1	4—NO_2—	0 (ditto)
4—CH_3COO	1 (a)	4—CN	0 (ditto) (a)
3—CH_3O—4—C_6H_5COO—	1	4—COOH	0 (ditto) (a)
2, 5—di—OH—	1	4—$COOC_2H_5$	0 (ditto) (a)

(a) Prepared in this laboratory.

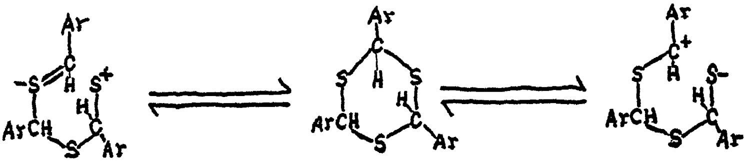
The following related compounds were also prepared:

Compound	No. of Trimers Formed
trithiocinnamaldehyde	2 forms
trithiofurfural	2 forms
trithio-2-thenaldehyde	2 forms
trithio-3-thenaldehyde	2 forms (a)
trithio-2-ethoxy-l-naphthaldehyde	1 form

(a) Prepared in this laboratory.

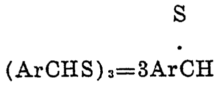
A theory which accounts for most of the cases is as follows:

Just as predicted by the laws of probability, an aryl thioaldehyde may trimerize to give both *cis-cis* and *cis-trans* forms of the puckered "chair" form. (No "boat" forms have been found (4).) In some cases, the resulting trimers are unstable due to the presence of certain labilizing groups on the aromatic ring. One form is always less stable than the other form. The influence of the substituent is due to its electron-attracting or electron-releasing effects.



Carbonium ion

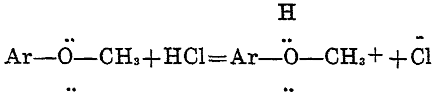
Thus a strong electron-releasing group Ar would allow carbonium ion formation and promote rearrangement of the α to the more stable β form. In the same way a strong electron-attracting Ar group would promote carbanion formation and have a similar effect. Polymer formation would be promoted in either case, and might predominate even over the β-trimer. The above dissociation can just as readily be written:



$$(\mathrm{ArCHS})_3 = 3\mathrm{Ar}\overset{\overset{\displaystyle \mathrm{S}}{\cdot}}{\mathrm{CH}}$$

In this case the same reasoning applies, and dissociation is promoted by either electron-releasing or electron-attracting substituents on the aromatic ring. Thus extremely stable trimers were isolated in two forms, extremely unstable ones dissociate and form polymers, and intermediate stability is represented where only one form was isolated. The dissociation to monomer actually occurs, as shown by the fact that cryoscopic molecular weight determinations of the trimers which are obtained in only one form are usually low (see experimental values).

A glance at Table I shows that all of the aldehydes which yield only one trimer have strong electron-releasing groups, i.e. hydroxy or acyloxy or strong electron-attracting groups, i.e. nitro. Since acyloxy compounds yield only one isomer, it is surprising that methoxy compounds yield two, as methoxy groups are also strongly electron-releasing. It is possible that the hydrogen chloride used as a catalyst coordinates with the ether linkage, forming a weak electron-attracting group, thus permitting both α- and β-forms to be isolated (Note I).



$$\mathrm{Ar}-\underset{\cdot\cdot}{\overset{\cdot\cdot}{\mathrm{O}}}-\mathrm{CH_3}+\mathrm{HCl}=\mathrm{Ar}-\underset{\cdot\cdot}{\overset{\overset{\displaystyle \mathrm{H}}{\cdot\cdot}}{\mathrm{O}}}-\mathrm{CH_3}+\ +\overset{-}{\mathrm{Cl}}$$

This possibility is substantiated by the observation that when anhydrous zinc chloride is used as a catalyst with anisaldehyde, only the β-isomer of the trithial is obtained, along with linear polymer. A nitro group alone prevents trimerization, but 3-nitro-4-anisaldehyde has two counter-influences in the 3-nitro and 4-methoxy groups, the latter of which does not now coordinate due to lack of basicity (note ortho-nitroaniline).

The lack of a second isomer of *m*-methoxybenzaldehyde can only

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Note I. The coordination of hydrogen chloride with ethers is well known; thus anisaldehyde is quite soluble in concentrated HCl, but insoluble in water. Benzaldehyde is insoluble in concentrated HCl.

be explained on the basis of poor technique. It should be present, but may be difficult to isolate.

Compounds which yield two isomers, such as the halogen or alkyl-substituted benzaldehydes, have only weakly electron releasing groups present. It is probable that further work will show that two isomers of trithiomesitaldehyde do exist.

Since the nitro-group was the only strong electron-attracting group which had been incorporated in the molecule, we tried several other such groups with the same results. When p-cyanobenzaldehyde, p-carboxybenzaldehyde, and p-carbethoxybenzaldehyde were treated with hydrogen chloride and hydrogen sulfide in alcohol, only linear polymers of high molecular weight were obtained.

Amino- and substituted amino-groups should represent good examples of electron-releasing and, in acidic solution, electron-attracting groups. p-Aminobenzaldehyde polymerized in acidic solution, but when p-dimethyl- and p-diethylaminobenzaldehyde were treated in the usual manner, crystalline trimers were obtained, only one form being isolated (Table II).

TABLE II. Aminobenzaldehyde products.

Product	M.P.	% Yield	Anal, % S		Mol. Wt.	
			Calcd.	Found	Calcd.	Found
$(p\text{-}(CH_3)_2NC_6H_4CHS)_3$	224-5°	81	19.40	20.00	495	467
$(p\text{-}(C_2H_5)_2NC_6H_4CHS)_3$	146-8°	82	16.59	16.48	579	535
$(p\text{-}CH_3CONHC_6H_4CHS)_3$	174-6°	70	17.88	17.79		(none)
$(p\text{-}C_6H_5CONHC_6H_4CHS)_x$	264-6°	35	13.29	13.99		(none)

p-Acetaminothiobenzaldehyde was obtained also in what was apparently a trimeric form, but no cryoscopic solvent was found for it. Bromoform was found useful for the dialkylaminothiobenzaldehydes and oxygen-substituted compounds, but could not be used for the acetamino- and benzoylamino-compounds. p-Benzoylaminobenzaldehyde apparently formed a polymer, having 16 or 17 units in the chain. When the trithio-p-acetaminobenzaldehyde was hydrolyzed by boiling in aqueous HCl, some hydrogen sulfide was evolved, and a complex polymer was formed! It may be safely stated that the dimethylammonium and diethylammonium groups function as strong electron-attracting groups also, permitting only one trimer to be obtained.

Experimental

Trithio-p-acetoxybenzaldehyde: A solution of 10.1g (0.062mole) of p-acetoxybenzaldehyde in 40 ml. of glacial acetic acid containing 5ml. of propionic acid was cooled to 0° in an ice bath. Hydrogen sulfide and hydrogen chloride were passed into the solution for two hours, after which the mixture was allowed to stand in the cold for one hour. The slurry of crystals was poured into cold water with stirring, and the solid filtered out and dried. The crude product was recrystallized repeatedly from methanol, yielding glittering white needles which melted at 186-7°. The yield of purified material was 2.8g. or 25%.

Anal: Calcd. for $C_{27}H_{24}O_6S_3$; %S, 17.89; m.w. 540. Found; %S, 18.06; m.w. (Cryoscopically in bromoform) 467.

When the above compound was hydrolyzed by refluxing in a mixture of ethanol and hydrochloric acid for four hours, p-hydroxybenzaldehyde was obtained in 82% yield.

Its identity was further confirmed by conversion to p, p'-diacetoxystilbene, as follows: 2.0g of trithio-p-acetoxybenzaldehyde was refluxed in 40 ml. of xylene with 2.0g of copper powder for sixteen hours, and the hot solution filtered. On cooling, a precipitate formed which yielded long white needles, after recrystallization from nitro-methane, which melted at 211-213°. ter Meer (10) reported p,p'-diacetoxystilbene to melt at 213°.

Confirmation of the *cis-trans* configuration for trithio-p-acetoxybenzaldehyde was obtained by its preparation from trithio-p-hydroxybenzaldehyde, which had previously been prepared by Kopp (11). A solution of 2.0g of trithio-p-hydroxybenzaldehyde in 15 ml. of acetic anhydride containing 5g of anhydrous potassium acetate was heated on a steam bath for two hours and poured into 50 ml. of cold water. The solid was recrystallized several times from methanol, yielding 75% of the theoretical amount of glittering white needles which melted at 187-188°, and caused no depression in melting point when mixed with the compound prepared from p-acetoxybenzaldehyde.

Trithio-4-thymolaldehyde: 4-thymolaldehyde was prepared by the method of Adams and Montgomery (12). A solution of 3.0g (0.02 mole) of this substance in 40 ml. of ethanol was cooled to —3° in an ice-salt bath, and hydrogen sulfide gas slowly bubbled in the mixture. After 10 minutes hydrogen chloride was also bubbled through the solution, and the temperature was maintained at —5° to +3°. The solution became quite viscous after two hours, and was allowed to stand in the cold for two hours longer, but no precipitate appeared. It was then poured into 200 ml. of cold water with stirring, and the white solid crystallized from hot 50% aqueous ethanol in white needles which weighed 2.8g (76%) and melted at 245-246°.

Anal: Calcd. for $C_{33}H_{42}O_3S_3$; %S, 16.48, m.w., 582. Found; %S, 16.40, m.w. (Cryoscopically in glacial acetic Acid) 483.

α-and β-Trithio-3-thenaldehydes: A solution of 5g (0.045 mole) of 3-thenaldehyde (13) in 30 ml. of a one-third saturated solution of hydrogen chloride in ethanol was cooled to —15° in a Dry Ice-ether bath, and hydrogen sulfide was bubbled into the mixture for one and one-half hours. The solution turns red, and finally forms a slurry of yellow crystals. After standing at —5° for one hour, the solid was removed, washed with cold ethanol, and dried. It weighed 5.6g (98%). It was extracted by refluxing with three 50ml. portions of boiling benzene, and the residue recrystallized from chloroform to yield small white needles of the β-isomer, melting at 217-218°, and weighing 1.4g (25%).

Anal: Calcd. for $C_{15}H_{12}S_6$; %S, 50.01, m.w. 384. Found; %S, 49.98, m.w. (Cryoscopically in napthalene) 378.

The benzene extracts of the crude thioaldehyde were evaporated to dryness on a steam bath, and the residue recrystallized twice from nitro-methane, yielding thick white needles of the α-isomer, which melted at 179-180° and weighed 1.7g (30%).

Anal: Calcd. for $C_{15}H_{12}S_6$; %S, 50.01, m.w. 384. Found; %S, 49.88, m.w. 372.

When a small sample of the α-isomer was refluxed in benzene with a crystal of iodine, it was readily converted to the higher melting β-isomer.

Trithio-p-dimethylaminobenzaldehyde: This compound was prepared in a variety of ways, in an effort to isolate a second isomer, but since the same product was obtained in all cases, only the most convenient preparation is described. A solution of 3g (0.02 mole) of p-dimethylaminobenzaldehyde in 45 ml. of 10 N hydrochloric acid was cooled to —5° in an ice-salt bath, and a vigorous stream of hydrogen sulfide was passed through the mixture for one and one-half hours. The solution was then saturated with hydrogen chloride and allowed to stand for one hour. The yellow solution was diluted with 50 ml. of cold water and then made basic with 30% potassium hydroxide solution. The crude yellow precipitate was washed with water and recrystallized from nitromethane in slender yellow needles, which weighed 2.7g (81.4%) and melted at 224-225°.

Anal: Calcd. for $C_{27}H_{33}N_3S_3$; %S, 19.40, m.w. 495. Found; %S, 20.00, m.w. (Cryoscopically in bromoform) 467.

p, p' Di (dimethylamino) stilbene: A mixture of 0.54g of trithio-p-dimethylaminobenzaldehyde and 0.56g of copper powder in 30 ml. of xylene was refluxed for seven hours. The solution exhibited a strong violet fluorescence, and after removing the coper sulfide and cooling, deposited greenish-yellow crystals which weighed 0.22g (50%) and melted at 253-254°.

Anal Calcd. for $C_{18}H_{22}N_2$; %N, 10.53. Found; %N, 10.12.

Trithio-p-diethylaminobenzaldehyde: This compound was prepared by the same procedure as given for the dimethylamine derivative. In a typical experiment, 2.0g of p-diethylaminobenzaldehyde dissolved in 40 ml. of 12 *N* hydrochloric acid gave 1.8g (82%) of the pure thioaldehyde after recrystallization from nitromethane. The yellow needles melted at 196-198°.

Anal: Calcd. for $C_{33}H_{45}N_3S_3$; %S, 16.59, m.w., 579. Found; %S, 16.48, m.w. (Cryoscopically in bromoform) 535.

Trithio-p-acetaminobenzaldehyde: A solution of 6g (0.037 mole) of p-acetaminobenzaldehyde (14) in 50 ml. of a one-fifth saturated solution of hydrogen chloride in "Cellosolve" was cooled to —25° in a Dry-Ice-ether bath, and a slow stream of hydrogen sulfide introduced for two hours. The viscous yellow mixture was let stand one hour, and then poured into 150 ml. of cold water with vigorous stirring. The oil which precipitated solidified and was crystallized from ethanol, yielding 4.5g (70%) of white crystals which melted at 174-176°.

Anal: Calcd. for $C_{27}H_{27}O_3N_3S_3$; %S, 17.88. Found; %S, 17.79.

When the above experiment was carried out in ethanol solution, a product which melted at 261-262°, and was insoluble in most organic solvents, was produced. Sulfur analysis for this compound was less than the calculated value for a trimer. Its properties suggest a linear polymer.

p-Benzoylaminobenzaldehyde oxime: Pfeiffer (15) reports the melting point of p-benzoylaminobenzaldehyde as 146-147°. When p-aminobenzaldehyde was benzoylated by the Hinsberg method in dioxane, and the product recrystallized from ethanol-water mixture, a 77% yield of a white solid which melted at 149-150° was obtained. The oxime has not previously been reported. It was prepared by the usual procedure and recrystallized from ethanol, and melted at 192-194°.

Anal: Calcd. for $C_{14}H_{12}O_2N_2$; %N, 11.66. Found; %N, 11.74.

p-Benzoylaminothiobenzaldehyde: A suspension of 24g (0.107 mole) of p-benzoylaminobenzaldehyde in 300 ml. of ethanol was cooled to 0° in an ice-salt bath, and hydrogen sulfide and hydrogen chloride passed into the mixture for three hours. The mixture was allowed to come to room temperature, and the solid collected, washed with water and dried. The 25g of crude product was dissolved in 200 ml. of boiling pyridine, and 100 ml. of chloroform added to the hot solution. On cooling, 9.0g of a white compound melting at 264-266° was obtained.

Anal: Calcd. for $C_{14}H_{11}ONS$; %S, 13.29. Found; %S, 13.99.

Assuming that the above compound is a linear polymer of the type, $HS(RCHS)_xH$, the approximate value of x may be calculated from the sulfur analysis as follows:

let p = % Sulfur by analysis
w—molecular weight of monomeric thial

$$\text{then } p = \frac{(32 + 32_x)\,100}{34 + xw}$$

$$\text{or } x = \frac{3200 - 34p}{pw - 3200}$$

For the above analysis,

$$x = \frac{3200 - 34 \cdot 14}{241 \cdot 14 - 3200} = 17$$

Linear Polymers: When p-cyanobenzaldehyde, p-carboxybenzaldehyde, and p-carbethoxybenzaldehyde were treated with hydrogen sulfide and hydrogen chloride in cold solutions, only intractable, evil-smelling substances which were insoluble in most solvents, were obtained. Some of these were plastic in nature, and most of them contained less than the calculated amount of sulfur, indicating that the polymers formed were of the type $HS(RCHS)_x(RCHO)_yH$. All efforts to prepare crystalline trimers were fruitless.

Summary

A theory which reconciles the apparently conflicting evidence for puckered and planar configuration of the trithiane ring has been advanced. This assumes that the ring exists in only one puckered "chair" form, and unsymmetrical trithianes may form *cis-cis* and *cis-trans* isomers of this form. Evidence in support of this theory is cited.

A number of new triaryltrithianes and derivatives have been prepared and characterized, including trithio-p-acetoxybenzaldehyde, trithio-4-thymolaldehyde, α and β-trithio-3-thenaldehyde, trithio-p-dimethylaminobenzaldehyde, trithio-p-diethylaminobenzaldehyde, and trithio-p-acetaminobenzaldehyde.

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The Relative Ease of Esterification of Amino Alcohols

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Whenever in an organic compound two functional groups are present on nearby carbon atoms, each group modifies the properties of the other. For example, the *beta*-phenoxyethyl halides are relatively inert to metathetical reactions (1) which the simple ethyl halides undergo readily, and the hydroxyl groups of ethylene glycol react with hydrogen bromide much more slowly than does the hydroxyl group of methanol (2).

Although many hundred amino alcohols have been made for pharmacological testing, not much attention has been paid to the influence of the amino and hydroxyl groups on the chemical properties of each other. Glasstone and Schram (3) have shown that the hydroxyl group lowers the basicity of the amino group in a series of *beta*-amino-alcohols such as aminoethanol, 2-amino-1-propanol, etc. This is the result which would be predicted from the electron-attracting inductive effect of the hydroxyl group. Glasstone and Schram did not extend their work to amino alcohols wherein the amino and hydroxyl groups are separated by more than two carbon atoms.

Some years ago we became interested in studying the effect of the amino group on the properties of the alcoholic hydroxyl group. The reactions of alcohols are of two general types; those, such as dehydration and replacement by halogen, in which the entire OH group is lost; and those, such as esterification, in which only the hydrogen of the hydroxyl group is replaced. Tertiary alcohols, in which the electron pair of the C-O link is greatly displaced toward the oxygen atom, readily undergo the first type of reaction, while primary alcohols, in which the C-O link is relatively strong, are also stronger acids, and undergo the second type of reaction more readily. The amino group, which is relatively electron-attracting (-I effect) should tend to strengthen the C-O bond, and it would be predicted, therefore, that tertiary amino alcohols of the general type I would be more easily esterified and more difficult to dehydrate than the corresponding tertiary alcohols (II) without the amino group.

This prediction was verified, as far as dehydration is concerned, in earlier work from this Laboratory (4). Amino alcohols of type I, where R, R' and R" are methyl groups, are extremely resistant to dehydration until there are at least five carbon atoms ($n=4$) between the amino and hydroxyl groups. Whereas simple tertiary alcohols can be dehydrated by heating with iodine or copper sulfate, the amino alcohols studied in this work could not be dehydrated by such mild reagents, and it was necessary to use concentrated sulfuric acid or to pyrolyze the Grignard complex in order to obtain olefinic amines.

Other work (4, 5) on the preparation of amino alcohol esters with such reagents as benzoyl chloride indicated that the tertiary hydroxyl group is much more easily esterified than is the case with simple tertiary alcohols, but no quantitative data were reported. In the present work we investigated the esterification of a series of dialkylamino alcohols with acetic anhydride. The reactants were used in equimolar quantities, and the reactions were carried out at 100° for one-half hour. At the end of this time an aliquot portion of the reaction mixture was analyzed for acetic acid, and the remainder was hydrolyzed and the ester isolated. Duplicate runs were made in all cases; usually the results agreed within one or two percent. The results are recorded in Table I. Some alcohols not containing amino groups were esterified for comparison purposes; these results are also included in Table I.

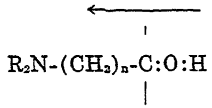
TABLE I. Esterification of Amino Alcohols with Acetic Anhydride in Benzene Solution.

100°C. 30 minutes.
0.2106 moles of each reactant

Alcohol Used	Percent of Ester Formed, Detd. By analysis	By distillation
$Me_2N-CH_2CH_2OH$	55	54
$Et_2N-CH_2CH_2OH$	83	83
$Me_2N-CH_2CH_2CH_2OH$	65	65
$Et_2N-CH_2CH_2CH_2OH$	76	—
$Me_2N-CH_2CHOH-CH_3$	81	78
$Me_2N-CH_2C(CH_3)_2OH$	69	70
$Me_2N-CH_2CH_2C(CH_3)_2OH$	86	84
$Me_2N-CH_2CH_2CH_2C(CH_3)_2OH$	53	54
CH_3CH_2OH	74	
$CH_3CH_2CH_2OH$	77	
$CH_3CHOH-CH_3$	46	
$(CH_3)_3C-OH$	11	

Certain conclusions may be drawn from the data in Table I. Secondary and tertiary alcohols containing an amino group in the molecule esterify much more completely than do alcohols of the same type without the amino group. A similar effect was not observed in the case of the primary alcohols, but this may not be significant, since primary alcohols without an amino group are easily esterified under the conditions used. In the case of tertiary alcohols the effect is still marked when the amino and hydroxyl groups are separated by four carbon atoms. The diethylamino alcohols apparently esterify more readily than do the dimethylamino analogs.

It seems to us that the effect of the dialkylamino group on the ease of esterification of an alcoholic hydroxyl group is due to two factors. The first factor undoubtedly is an electron-attracting inductive effect of the amino group operating, with diminished intensity, through the carbon chain:



$$\overset{\longleftarrow}{R_2N\text{-}(CH_2)_n\text{-}\overset{|}{\underset{|}{C}}:O:H}$$

As a result of this electron-displacement toward the nitrogen atom, the oxygen atom of the hydroxyl group has less share than usual in the electron-pair binding it to the carbon atom, consequently, the hydrogen atom of the hydroxyl group is held more loosely. The concept of simple inductive effect, however, does not explain the great ease of esterification of 4-dimethylamino-2-methyl-2-butanol, since the inductive effect of an electron-attracting group operating through a saturated chain does not usually continue through more than three carbon atoms. The acid strengths of the propionic acids may be cited as an example of this: propionic acid has $K_a=1.4 \times 10^{-5}$; alpha-chloro-propionic acid is much stronger, with $K_a=1.47 \times 10^{-3}$ but beta-chloropropionic acid is not much stronger as an acid than the unsubstituted compound; K_a in this case is 8.6×10^{-5}.

A second factor which appears to be important in explaining the effect of the amino group on the ease of esterification of amino alcohols is chelation. If the molecule of the amino alcohol "curls up," as in all probability it does, then the amino and hydroxyl groups approach very close in space, and a hydrogen bond can be formed.

Molecular models indicate that this type of hydrogen bonding can occur readily until six carbon atoms separate the two groups. When such a chelate ring takes part in a chemical reaction the proton can remain attached to either the nitrogen or the oxygen atom. This explains the reduced basicity of the amino group and the increased ease of esterification of the hydroxyl group. The difference in effect between the dimethylamino and diethylamino groups is probably one of basic strength-diethylamine is considerably stronger as a base ($K_b=1.26 \times 10^{-3}$) than is dimethylamine ($K_b=7.4 \times 10^{-4}$) (6) and hence would have a greater attraction for the proton.

It might seem that the greatly increased ease of esterification of the tertiary amino alcohols could be due to simple catalysis by the tertiary amino group, since tertiary bases such as pyridine are known to catalyze some alcohol-anhydride reactions. While catalysis may play some part, we do not believe that this is a complete explanation for the results obtained in the present work, as in general the reaction of tertiary alcohols with acetic anhydride is not markedly influenced by the presence of a tertiary base. For example, Mitchell, Hawkins and Smith (7) found that at 60° tertiary butyl alcohol and acetic anhydride gave only a 6% yield of ester, even though a large quantity of pyridine was present.

Experimental

Preparation of Amino Alcohols.—These were prepared as described previously (4,8) from the chlorohydrin or, in some cases, the olefin oxide and secondary amine. The amino alcohols were purified by distillation through a Whitmore-Fenske column packed with single turn glass helices, and only those fractions of constant boiling point and constant index of refraction were used. The physical constants of the fractions employed are shown in Table II.

TABLE II. Data on Amino Alcohols.

ALCOHOL	B.pt./Press.	n_D^{20}
$Me_2N\text{-}CH_2CH_2OH$	133-134/740	1.4292
$Me_2N\text{-}CH_2CH_2CH_2OH$	159-161/740	1.4360
$Me_2N\text{-}CH_2CHOH\text{-}CH_3$	124/740	1.4192
$Me_2N\text{-}CM_2C(CH_3)_2OH$	128/740	1.4212
$Me_2NCH_2CH_2C(Me)_2OH$	79-80/50	1.4289
$Me_2NCH_2CH_2CH_2C(Me)_2OH$	96-97/27	1.4393

Esterification of Amino Alcohols.—An accurately weighed sample (0.2106 mole) of the amino alcohol in 156 g. of reagent grade anhydrous benzene was placed in a 300 ml. glass ampoule, and 0.2106 mole (20 ml.) of reagent grade acetic anhydride was added from a calibrated pipet. The ampoule was quickly sealed, shaken and immersed in a thermostat at 100°, where it was kept for thirty minutes. It was then removed, cooled in an ice bath and opened. The contents were shaken with 100 ml. of distilled water to hydrolyze unreacted acetic anhydride, and the water layer was made basic with 6 N sodium hydroxide. The organic layer was separated, dried over anhydrous potassium carbonate, filtered, and placed in a 250 ml. volumetric flask, which was then filled to the mark with dry benzene. A 10 ml. portion of this solution was removed for analysis, and the remainder was distilled through a column packed with a tantalum spiral, and the yield calculated from the weight of ester isolated. The physical constants of the aminoalkyl acetates obtained are given in Table III.

TABLE III. Data on Aminoalkyl Acetates.

Aminoalkyl Group	B.p./ Press.	* n_D^{20}	d_4^{20}	MR_D Calc.	obs.	M.p. of HCl Salt
$Me_2N\text{-}CH_2CH_2\text{-}$	150/740	1.4161	0.9290	35.6	36.2	130-131
$Et_2N\text{-}CH_2CH_2\text{-}$	112/80	1.4238	0.9124	44.7	44.5	113-114
$Me_2N\text{-}CH_2CH_2CH_2\text{-}$	114/120	1.4207	0.9178	40.1	40.1	118-119
$Me_2N\text{-}CH_2CH(CH_3)\text{-}$	151/740	1.4133	0.9058	40.0	40.1	125-126
$Me_2N\text{-}CH_2C(CH_3)_2\text{-}$	159/740	1.4179	0.8955	44.7	44.8	143
$Me_2N\text{-}CH_2CH_2C(CH_3)_2\text{-}$	120/100	1.4257	0.8995	49.4	49.3	180-181
$Me_2N\text{-}CH_2CH_2CH_2C(CH_3)_2\text{-}$	119/50	1.4287	0.8902	54.0	54.2	133-134

Analytical Method.—The usual procedure for determining acetyl groups had to be modified because of the presence of the amino group, and the following technique was devised. The 10 ml. aliquot of the benzene solution was refluxed for one hour with methyl alcoholic sodium prepared by dissolving 0.5 g. of clean sodium in 14 ml. of reagent methanol, and adding 2 ml. of boiled distilled water. The solution was then distilled to dryness under reduced pressure in a small Kjeldahl apparatus. The residue was taken up in 10 ml. of distilled water and 5 g. of reagent sodium dihydrogen phosphate and 10 ml. of reagent 90% phosphoric acid were added. The mixture was distilled almost to dryness at 60 mm. pressure from an oil bath kept at 100°; the distillate was collected in a known volume of standarized barium hydroxide solution. Three 10 ml. portions of distilled water were added to the residue, the mixture being evaporated almost to dryness each time. The excess barium hydroxide was titrated to the phenolphthalein end point with 0.1 $\underline{N}$ hydrochloric acid. The whole operation, except the titration, was carried out in the same apparatus, which was protected from carbon dioxide by means of potassium hydroxide towers. Control experiments showed that the amount of acetic acid liberated could be determined with an accuracy of 1%.

Summary

1. The ease of esterification of certain amino alcohols by acetic anhydride has been determined under constant conditions. It has been shown that secondary and tertiary alcohols containing an amino group esterify much more readily than do the analogs without an amino group.

2. An explanation has been developed for these observations.

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The Relative Stability of Some Nickel (II) Complexes[2]

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Coordination compounds have received considerable attention because of the belief that an understanding of the forces which hold these combinations together may lead to a better understanding of the general nature of these forces. One indication of the strength of these bonds is to be found in the stability of the complexes. Very little study has been made of the stabilities of the nickel (II) complexes.

In view of this, a spectrophotometric study was made of the relative stabilities of some of the nickel (II) complexes using a Beckman model (DU) spectrophotometer to measure the transmittancy of the various anions in the range 225 mμ to 400 mμ at intervals of 10 mμ. Since each complex has certain characteristic features in its transmittancy, it was possible to compare curves of individual anions with those of mixtures of anions and establish relative stabilities of the complexes.

The only values found in the literature for instability constants were for the cyanide, bromide, and citrate complexes. Sartori (1) gives 3.45×10^{-16} for tetracyanonickelate (II); Bobtelsky and Jordan (2) give 4.1×10^{-4} for a citrate complex; and Job (3) gives 6.03×10^{-4} and 1.32×10^{-5} for $NiBr_2$ and $(NiBr)^-$ respectively in the presence of some HBr, but full details are not given in the article.

H. C. Jones (4) in a series of publications reported studies of absorption spectra of over 2000 different solutions. Very little data are given as to the relative or actual stabilities of the complexes.

Experimental

In order to compare the stability of the complex nickel anions, use was made of reactions of the type:

$$2\,K^- + (NiX_4)^{-2} + 4\,(K^+ + Y^-) \rightleftharpoons 2\,K^+ + (NiY_4)^{-2} + 4\,(K^+ + X^-).$$

The original complex was made in solution by adding the proper amount of potassium salt to the simple nickel compound, $(NiX_2 + 2\,KX)$. The solutions were 0.10 M nickel and 0.40 M anion. To the mixture, for comparison purposes, was added an equivalent amount of a second potassium salt (KY) for the possible formation of a complex of nickel with Y. Equilibrium was approached from both directions, i.e. starting with K_2NiX_4 and adding KY; starting with K_2NiY_4 and adding KX. The foregoing statement is true except for measurements using tartrate and thiocyanate, in these cases the potassium salt was added in all cases to the other nickel salts.

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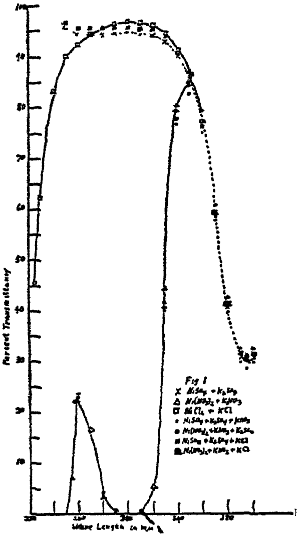
[2] Abstracted from the thesis presented to the faculty of Purdue University in partial fulfillment of the requirements for the M. S. degree, Feb 1948

Transmittancy measurements were made with a Beckman model (DU) spectrophotometer. The light source was a hydrogen discharge lamp. Silica cells were used; the one used for the water blank had a cross-section of 1.008 cm, the one for the solutions 1.003 cm. The temperature range was 23°C. to 30.5°C.

All salts were A.C.S. reagent grade except the potassium tetracyanonickelate (II) which was furnished by Dr. W. C. Fernelius. All water used was redistilled.

In figures 1, 2, 3, and 4, it is shown how the relative stability was established. In each figure the ordinate is the percent transmittancy and the abscissa is the wavelength in millimicrons.

The relative stability was established by comparing the transmittancy curve of a mixture of two anions being studied with the transmittancy curve of each anion. The curve of the anion that the mixture more nearly resembled was the curve of the more stable complex.



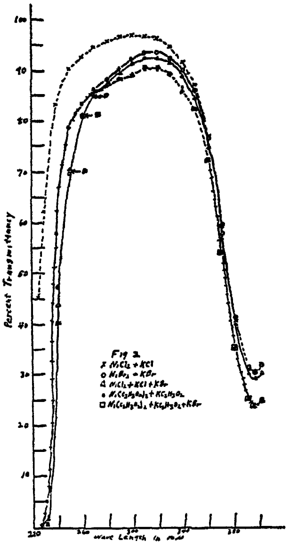
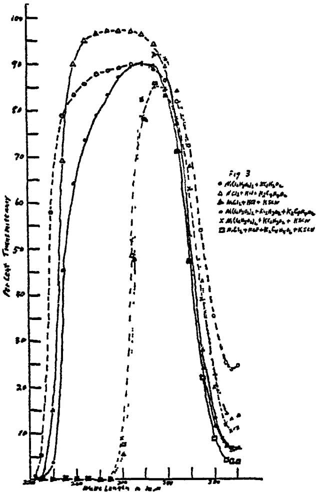


Fig. 1. Transmittancy curves for Nickel (II) complexes of X) Sulfate; △) Nitrate; □) Chloride; •) Sulfate and Nitrate; ○) Nitrate and Sulfate; ■) Sulfate and Chloride, ▲) Nitrate and Chloride.

Fig. 2. Transmittancy curves for Nickel (II) complexes of X) Chloride; ○) Bromide; △) Chloride and Bromide; •) Acetate, □) Acetate and Bromide.

Figure 1 shows that the sulfate, nitrate, and chloride have about the same degree of stability. The part of the curve from 250 mμ to 340 mμ in the case of all solutions containing nitrate is due to the nitrate ion itself.

Figure 2 shows that the bromide complex is more stable than the chloride complex and that the acetate complex is still more stable.



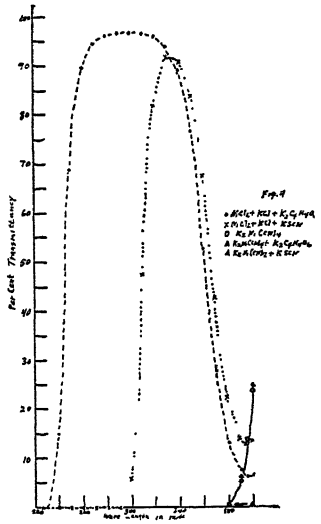


Fig. 3. Transmittancy curves for Nickel (II) complexes of o) Acetate; Δ) Tartrate; ▲) Thiocyanate; ●) Acetate and Tartrate; X) Acetate and Thiocyanate; □) Tartrate and Thiocyanate.

Fig. 4. Transmittancy curves for Nickel (II) complexes of •) Tartrate; X) Thiocyanate; o) Cyanide, ▲) Cyanide and Tartrate; ▲) Cyanide and Thiocyanate.

Figure 3 shows that the tartrate and thiocyanate complexes are both more stable than the acetate complex. The curve for the mixture of tartrate and thiocyanate is about half like one and half like the other so it was concluded that these two complexes had about the same degree of stability.

Figure 4 shows that the cyanide complex is the most stable of the complexes studied.

Results

The relative stability observed for the nickel (II) complexes, the most stable being listed first, is as follows:

Cyanide
Tartrate, Thiocyanate
Acetate
Bromide
Sulfate, Nitrate, Chloride.

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The Preparation of Some Dialkylaminoalkyl Esters of Phenoxyacetic Acids*

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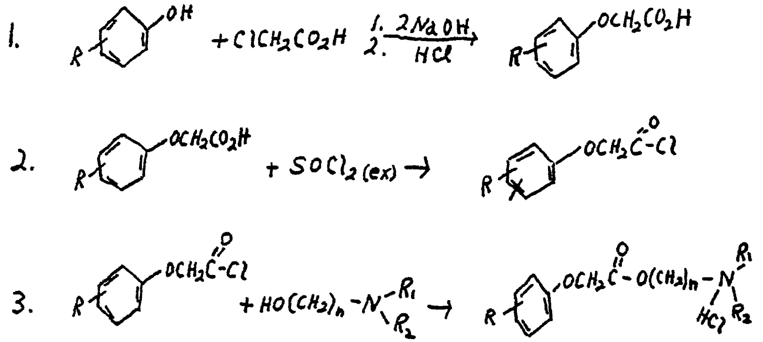
Ever since the elucidation of the structure of cocaine by Willstäter et al (1) in 1898, attempts have been made to synthesize better local anesthetics without the undesirable physiological properties of the natural product. One of the first of the synthetic local anesthetics, which was not closely related to cocaine in structure, was prepared by Einhorn and Uhlfelder (2) in 1909. This compound was the diethylamino-ethyl ester of p-aminobenzoic acid and was called "novocaine" or more recently "procaine."

Since the synthesis of "procaine," there have been literally thousands of compounds prepared and tested for local anesthetic activity; but, as yet, no one has managed to prepare a more versatile anesthetic. The results which have been obtained in this search are conflicting and vary over wide limits, and no general correlation of structure with physiological activity has been made in this field. This lack of correlation is most striking when one considers the lack of specificity in the acids which have been esterified with amino alcohols.

A search of the literature failed to reveal the preparation of dialkylaminoalkyl esters of any phenoxyacetic acids. The high activity of certain substituted phenoxyacetic acids as plant hormones (3) suggested the possibility of other physiological action. Therefore, a series of basic esters was prepared for test as local anesthetics. Meanwhile, Truitt et al (4) and Martin and Hafliger (5) reported the preparation of a large number of basic esters of various substituted phenoxyacetic acids for testing as antihistaminic agents. However, neither group reported any work on the esters of p-nitrophenoxyacetic acids and p-aminophenoxyacetic acids with which this work is concerned.

The procedure used for the preparation of the esters is illustrated by the equations:



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* Abstracted from a thesis to be submitted by Raymond Boucher to the faculty of Indiana University in partial fulfillment of the requirements for the degree Master of Arts in the Department of Chemistry.

$R = H$, NO_2 - , 2 , 6 - $diCH_3$
$N = 2$, 3
R_1 and $R_2 = CH_3$, C_2H_5, N - C_3H_7, N - C_4H_9, β - morpholino
$R_1 = \Phi$, $R_2 = C_2H_5$

The method of Jacobs and Heidelberger (6) was used to prepare both the p-nitrophenoxyacetic acid and the p-nitrophenoxyacetyl chloride. The esterification reaction was run in dry benzene from which the product usually separated as a heavy oil which crystallized on cooling. Absolute ether was added to the cold benzene solution to precipitate the remainder of the salt. All the hydrochlorides but one (the morpholino derivative) were very hygroscopic so that the isolation and recrystallization were difficult. In general the compounds were recrystallized from absolute alcohol-absolute ethyl acetate mixtures or from the latter solvent.

Attempts to isolate the products obtained after reduction using Adam's Catalyst (on the free bases) and Palladium on charcoal (on the hydrochlorides) presented many difficulties and at best only small yields of impure product were obtained. The p-aminophenoxyacetic acid esters obtained were oxidized even on very brief exposure to air, causing the reduced alcohol solutions to become intensely colored. Since these compounds were being prepared to be tested as local anesthetics, this extreme instability was very disadvantageous. Attempts to distill the free bases under reduced pressure resulted in decomposition and only tars were obtained as a residue. The hydrochlorides were precipitated with absolute ether and were highly colored viscous oils or glasslike amorphous solids which would not crystallize.

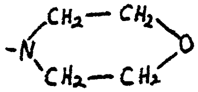
The decomposition of p-aminoethers in the presence of mild oxidizing agents was studied quite thoroughly in the case of p-anisidine (7) as early as 1910. Wieland assumed that the decomposition occurred with the formation of an intermediate quinoid structure. Aniline, methanol and anisole were isolated from the reaction mixtures even after the reactions had been run only a few minutes. It is then reasonable to assume that similar decomposition probably occurs with the p-aminophenoxy acetates. No attempts were made to isolate any of the probable breakdown products in this decomposition reaction.

$$p - X\,\Phi - OCH_2CO_2(CH_2)_n - NR_1R_2$$

Experimental

Diethylaminoethyl phenoxyacetate hydrochloride: A solution of 8g (0.046 mole) of phenoxyacetyl chloride in 65 ml of dry benzene was placed in a three-necked flask equipped with a reflux condenser, a mechanical stirrer and a dropping funnel. A solution of 8g (0.068 mole) of β-diethylaminoethanol in 30 ml of dry benzene was added drop-wise to the vigorously stirred cold acid chloride solution at such a rate that no hydrogen chloride fumes were perceptible. A light yellow oil, which crystallized to a white amorphous solid, separated from the reaction

TABLE I. Properties of Esters.

X	n	R₁	R₂	Yield %	*M.P. °C	Chlorine% Calcd.	Chlorine% Found
H	2	C_2H_5-	C_2H_5-	79	112-3.5	12.04	11.79
NO_2	2	CH_3-	CH_3-	71	164-5	11.63	11.40
NO_2	2	C_2H_5-	C_2H_5	83	107-8	10.66	10.45
NO_2	2	n-C_4H_9-	n-C_4H_9-	52	88-90	9.12	9.23
NO_2	2	C_2H_5-	C_6H_5	41	133-4	9.13	9.18
NO_2	2			63	192-3	10.22	10.19
NO_2	3	n-C_3H_7-	n-C_3H_7	72	88-9	9.43	9.28
NO_2	3	n-C_4H_9-	n-C_4H_9	72	108-9	8.80	8.51
NO_2	3	n-C_4H_9-	n-C_4H_9-	20-5	144-7	9.51	9.52

* Uncorrected.

mixture. The ester hydrochloride was recrystallized twice from an absolute alcohol-absolute ether mixture. (Properties in Table I.)

Dialkylaminoalkyl esters of p-nitrophenoxyacetic acid:

Diethylaminoethyl p-nitrophenoxyacetate hydrochloride: This compound was prepared using the same procedure as was used for the diethylaminoethyl phenoxyacetate hydrochloride except that in this case the reaction mixture was allowed to reflux for about 30 minutes after complete addition to the aminoalcohol. A solution of 22g (0.19 mole) of diethylaminoethanol in 100 ml of dry benzene was added to a solution of 40g (0.19 mole) of p-nitrophenoxyacetyl chloride (6) in 150 ml of dry benzene. A viscous light brown oil, which solidified on cooling, separated from the reaction mixture. About 200 ml of absolute ether was added to the benzene solution to insure complete precipitation. The ester hydrochloride was recrystallized twice from 5% absolute methanol in absolute ethylacetate. (An alternative recrystallization procedure was to dissolve the ester hydrochloride in absolute alcohol and add absolute ether until a cloudiness develops.) (Properties in Table I.)

The same general procedure was used in the preparation of all the p-nitrophenoxyacetate hydrochlorides.

Dialkylaminoalkyl p-aminophenoxyacetates: Distilled water solutions of 20g (0.05-0.065 mole) of the p-nitrophenoxyacetate hydrochlorides were treated with dilute sodium carbonate solution until the solution was basic. The heavy oils which separated from the basic solution were extracted with three 50-75 ml portions of ether and the ether extracts combined and placed over anhydrous sodium sulfate. The dried extracts were filtered and the ether removed under reduced pressure leaving close to the theoretical amount (95-100%) of viscous light yellow oils. The free bases were taken up in 125 ml of absolute alcohol and 0.2g of platinum oxide catalyst added. The reductions were done using low pressure hydrogenation apparatus (initial pressure about 40-45 lbs.) and the reduction began immediately. The reaction mixture warmed considerably as the reduction proceeded and the theoretical amount of hydrogen was used up in about 15-30 minutes, depending on the ester being reduced. The catalyst was removed by filtration or centrifugation and the alcohol solutions concentrated under reduced pressure yielding highly colored concentrates which were taken up in ether. Dry hydrogen chloride gas was passed into the ether solutions to precipitate the amine hydrochlorides.

Reduction of the p-nitrophenoxyacetate hydrochlorides was done in the same manner using Palladium on charcoal as a catalyst. Absolute ether was added directly to the filtered absolute alcohol solution to precipitate the amine hydrochlorides.

Summary

The following esters have been prepared from the appropriate acid chloride and aminoalcohol: β-diethylaminoethyl phenoxyacetate hydrochloride, β-dimethylaminoethyl p-nitrophenoxyacetate hydrochloride, β-diethylaminoethyl p-nitrophenoxyacetate hydrochloride, β-di-n-butylaminoethyl p- nitrophenoxyacetate hydrochloride, β-ethyl-β-phenylaminoethyl p-nitrophenoxyacetate hydrochloride, β-morpholinoaminoethyl p-nitrophenoxyacetate hydrochloride, γ-di-n-propylaminopropyl p-nitrophenoxyacetate hydrochloride, γ-di-n-butylamino-propyl p-nitrophenoxyacetate hydrochloride, and γ-di-n-butylaminopropyl p-aminophenoxyacetate hydrochloride.

The difficulties encountered in the attempted catalytic reduction of the p-nitrophenoxyacetates are discussed.

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The Distribution of Carbon Between the Zirconium and Ferrite Phases[1]

W. P. Fishel, John C. Hayes[2], Vanderbilt University

A previous investigation by Rhoad (1), on the distribution of carbon between the zirconium and ferrite phases, confirmed the existence of zirconium carbide (ZrC) as a crystalline constituent, which could be identified microscopically, and which could be separated by the solution method. It also indicated that in some iron-carbon-zirconium alloys, part of the zirconium occurred in some form which was soluble in dilute acids. This work is concerned mainly with the carbide forming tendency of zirconium, and the effect of zirconium on the carbon content of the eutectoid mixture.

Zirconium in iron-carbon alloys is capable of reacting with carbon to form zirconium carbide (ZrC), and with iron to form iron zirconide (Fe_3Zr_2). Its distribution between these two phases must depend upon the affinities of zirconium for iron and carbon, and the relative atomic ratios of these elements present in the steel. Indications are that both are practically insoluble in solid iron. Hence, they could not contribute to precipitation hardening, and should be considered as inclusions.

In order to be a part of the Ar_1 transformation, zirconium carbide must separate from the austenitic solid solution at the Ar_1 temperature. If zirconium does take part in this transformation, the percent of carbon in the eutectoid mixture will be increased or decreased, depending upon the effect of zirconium on the Acm and A_3 transformations.

Zirconium occurring as a solid solution with ferrite should be found in the solution of the reagent used to dissolve the steel sample. If zirconium is an avid carbide former, it would be expected that in steels whose atomic ratios of carbon to zirconium are less than one, all of the carbon would form zirconium carbide, and the remaining zirconium would form a solid solution with ferrite. If the atomic ratio of carbon to zirconium is greater than one, all the zirconium would form zirconium carbide. However, if zirconium is not a strong carbide former, then the presence of other elements would influence the distribution of carbon to a greater extent. Some relation similar to the mass law would apply.

The iron-carbon system of Vogel and Loehberg (2) which is approximated from their data shows that the carbon content of the iron-carbon (carbide) eutectoid increases progressively with zirconium. Shapiro and Strauss (3) have interpreted this diagram to mean that the carbon content in the eutectoid mixture is increased with increasing zirconium. This may be true, but it does not take into account the fact that zirconium forms a carbide. If zirconium forms a carbide, the amount of carbon necessary for this formation is removed from solution, and more carbon is then necessary for the formation and separation of the eutectoid mixture. If zirconium does increase the carbon content in the eutectoid mixture, then zirconium must take part in the eutectoid separation and must be a part of it.

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[1] This paper contains material from the thesis of John C. Hayes, presented to the faculty of Vanderbilt University, in partial fulfillment of the requirements of the M S degree, June, 1944.

[2] Present address: Chemistry Dept., Purdue University.

Experimental Procedure

Several zirconium steels were prepared by melting pure materials in an induction furnace, fitted with a silica tube for vacuum melting. An evacuated system was used due to the ease with which zirconium unites with oxygen and nitrogen. The alloying agents used were Armco iron, graphite, zirconium carbide, and ferro-silicon-zirconium. The Acheson graphite crucibles were lined with a mixture of four parts sintered and ground magnesium oxide to one part unsintered magnesium oxide, moistened with a saturated solution of magnesium chloride. The lined crucibles were baked at 120°C. for several hours and then baked in the induction furnace for 10-15 minutes before the charge was added. The ingots were turned down on a lathe to sound metal, and then turnings were collected for chemical analyses. A section was cut from the sound metal of each alloy for microscopic analysis.

Analytical Procedure

The method used to separate zirconium occurring in the carbide phase from that occurring in some other phase was by digesting the ingot turnings in hydrochloric acid (sp. gr. 1.1) and then determining the amount of zirconium dissolved and that undissolved. The zirconium found in the residue was considered to be zirconium carbide, and that soluble in the acid to be zirconium occurring in some other phase. Zirconium was determined by precipitation with phenylarsonic acid, according to Rhoad (1).

> Carbon was determined by the standard combustion method, using 2.0 gm. samples.
>
> No determination was made for the silicon present in any alloy.
>
> A summary of the analysis of the alloys of this study is given in Table I.

Discussion

By plotting the atomic ratios of zirconium to carbon against the percent of the total carbon existing as zirconium carbide, figure I is obtained. The carbon united with zirconium was calculated from the zirconium found in the residue. This diagram shows that all the carbon exists as zirconium carbide if the atomic ratio of zirconium to carbon

TABLE I

ALLOY	% C.	% Zr	% Zr / % C	% of Total / Zr. in Res	At. % Zr. / At% C	C as ZrC / % of Total
2	0.14	0.13	0.93	100.00	0.12	12.24
3	0.16	0.071	0.44	100.00	0.06	5.85
5	1.11	0.254	0.23	25.66	0.03	3.02
6	0.56	0.086	0.15	86.03	0.02	2.02
7	2.92	0.923	0.32	78.76	0.04	4.17
11	0.168	1.62	9.65	100.00	1.32	100.0
12	0.16	1.58	9.75	87.00	1.28	100.0
Rhoad's Samples						
9	0.75	1.315	1.75	61.75	0.23	23.12
13	0.86	0.958	1.11	94.5	0.15	14.69
14	0.56	1.246	2.22	56.8	0.29	29.3
15	0.86	0.306	0.36	44.0	0.05	4.8
18	1.52	1.993	1.31	79.8	0.17	17.2

is greater than one. Data for atomic ratios of zirconium to carbon between .3 and 1.28 is lacking. The points for atomic ratios below .3 form almost a straight line, which seems to indicate that a distribution law must apply in this case.

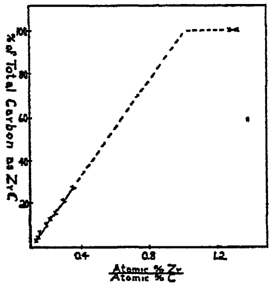

Figure I

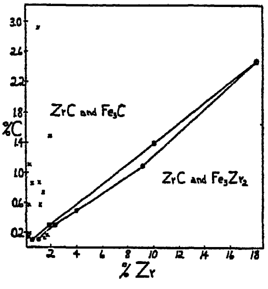

Figure II

The data obtained from the alloys of this study and from those of Rhoad (1) agree with the inferences of figure II, which is approximated from the data of Vogel and Loehberg (2). All alloys above the curve show zirconium carbide, and iron carbide, as pearlite or as pearlite and cementite. In this area the ratio of zirconium to carbon is less than one. The two points below the curve are alloys No. 11 and No. 12, which showed zirconium carbide, and a lacy network which is probably iron zirconide, but no iron carbide was present. In this area, the ratio of zirconium to carbon is greater than one.

The preparation of a group of zirconium steels, whose atomic ratios of zirconium to carbon varied widely, was difficult. Zirconium carbide and ferro-silicon-zirconium were the only available sources of zirconium. The quantity of zirconium carbide was very limited, and when alloys were prepared with this compound, the percent of zirconium to carbon could not be varied. The ferro-silicon-zirconium contained about one-third zirconium and about one-half silicon, so that a large amount of silicon was necessarily present.

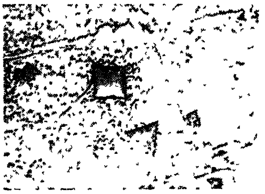

Figure III

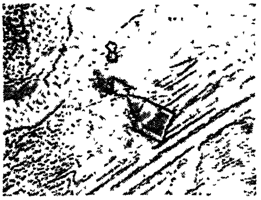

Figure IV

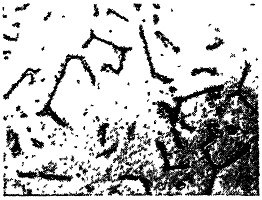

Figure V

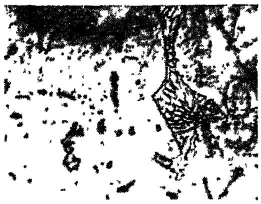

Figure VI

Fig. 3. Alloy #7, unetched. X750. Zirconium Carbide Crystals. Zr. =0.923% (0.732% insol.) C=2.92%.

Fig. 4. Alloy #7. Etchant: sodium picrate. X750 Zirconium carbide crystals and cleavage planes cementite.

Fig. 5. Alloy #12. Etchant: nital. X750 abundance of crowfoot structure.

Fig. 6. Alloy #11. Etchant: nital. X750. Lacy network and absence of pearlite.

Zirconium and the Eutectoid Mixture

In order to show that zirconium does not take part in the eutectoid transformation, three of the samples (Nos. 5, 7, and 12) which showed an abundance of zirconium carbide crystals and crowfoot structure, were held at 400°C. for two hours, then quenched in ice water. If zirconium takes part in the Ar_1 transformation, it must go into solution on heating and reprecipitate at the Ar_1 temperature. A section from each of the quenched samples was polished and examined. This examination revealed the presence of the crowfoot structure, characteristic of ZrC. The form and the amount of ZrC had not been changed by the heating and the quenching. Since the ZrC structure is still present at 900°C., its formation must occur at a higher temperature. According to

Vogel and Loehberg, the temperature of this formation is about 1330°C. for alloys rich in Zr, and about 1145°C. for those poor in Zr. (figure 7.)

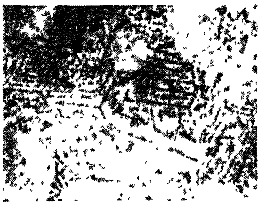

Fig. 7. Alloy #5. Unetched. X700. 900° for two hours, water quenched.

Conclusions

1. All the carbon in a steel whose atomic ratio Zr:C is greater than 1, will be united with the Zirconium.

2. If the ratio Zr:C is less than 1, there is a fairly direct ratio between this and % of Total carbon as ZrC.

3. Fe_3C appears only if Zr:C is less than one.

4. Zirconium does not enter Ar_1 transformation because ZrC separates in the crystalline or crowfoot structure at a temperature well above the Ar_1; *therefore zirconium* does not increase the carbon content of the eutectoid, as stated by Strauss.

However in order to have a matrix of pearlite, the steel must contain more than 0.85% C. The excess carbon unites with zirconium, and is in no way connected with the eutectoid separation.

5. ZrC particles in steels function as inclusions *only*.

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The Chemistry of Controlled Mutations

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Mutations may be produced in plants and animals in three ways. In a few cases a reasonably accurate prediction of mutation that will occur under carefully controlled conditions can be made. We have recently become much more interested in the study of the causes of cancer. We know that a tendency to acquire cancer may be inherited. Studies of cancer in animals have shown that some strains of laboratory animals are much more susceptible to cancer than are other strains. Since cancer itself is not inherited it is not considered to be a mutation. Natural mutations do occur, but hybridization and selection somewhat increase their frequency of occurrence. This method of producing mutations has given mankind many of the plants and animals that now exist. The Concord grape and the Starking apple are good examples of mutations produced by this method. The seedless orange and the seedless grape are also mutations of more or less accidental origin. There is safety in numbers. Only by producing a large number of plants is there very much chance of a mutation occurring. Mutations are not always improvements. They may be of less value than the parent type in many instances. Those types of little worth are seldom propagated while the more valuable types are very commonly grown.

The second method of producing mutations is by the use of radiations. The X-ray is probably the most valuable of all radiations in producing new varieties of plants. Radioactive elements and compounds may give us many kinds of mutations in plants and animals. Their present use is largely confined to studies in growth and nutrition. The chemical changes occurring in plant and animal life can be traced by means of radioactivity.

The third way of producing mutations is by chemical treatment. When a chemical compound or mixture partially dissolves a cell wall and acts within the cell it is very effective in the production of mutations. It is well known that it is difficult to determine whether some kinds of living cells are plant or animal. There are many instances of chemically induced mutations in plants but it is more difficult to determine how mutations may be produced in animal life. From the similarity in cell structure it would seem that any chemical that proved to be particularly effective in making cellular changes in plants might be expected to perform a similar function in changing the cell structure in animals. The first mutation that commonly occurs when certain forms of animal life are given proper doses of certain chemical mixtures is the increased rate of reaction to stimuli. The response may be more easily produced with a comparatively weak stimulus with a decrease in reaction time. Bees and other insects show an ability to assimilate the chemicals quite rapidly and show a decrease in reaction time by moving the wings more rapidly and producing a tone of higher pitch than the controls that were not given the chemicals. Pigeons show a more rapid response to a stimulus applied to either of their feet. Their increased ability to quickly find their way through a maze shows that there may be a corresponding increase in intelligence when they are fed these chemicals. There seems to be some increase in flying ability. As it has been impossible for accurate measurements to be made because of the lack of adequate equipment these observations cannot be regarded as scientific evidence but are merely my own opinion on this matter. Cuprammonium hydroxide, ethyl nitrate, and partially nitrated cellulose may be used to make up a chemical mixture for this purpose. It is probable that glutamic acid could be given immediately after the cuprammonium hydroxide solution to obtain similar results. These chemicals must be given in very small amounts which can be determined only by experimentation.

Hyperglycemia may be expected to be a symptom of a slight overdose of a mixture of these chemicals. An amount must be given that is sufficient to produce a physiological reaction. The chemicals tend to have an accumulative action when several doses are given. As cases of fusion occur in plants in quite a few instances it seems reasonable to assume that a similar fusion of axones of neurones may be the cause of a lessened reaction time in animals. There are two theories of impulse conduction; the contact theory and the continuity theory (1). It has been shown that an axone could be excited by placing it very near another axone of the same type which received an electrical stimulus (2). It has been suggested that life originated by chemical combinations of nonliving matter (3, 4). This opinion does not imply that life was not created.

The chemical treatment of plants is not difficult, but no result may occur if the solution is too dilute. Serious burning of the foliage and other undesirable results are apt to occur when too strong a solution is used. A strong solution usually produces an undesirable mutation. To make a solution, ammonium hydroxide is mixed with copper sulfate until all the mixture is of a purple color, then a mixture of napthalene and carbon disulfide is added to it. One ounce of cuprammonium hydroxide shaken well with an ounce of a saturated solution of napthalene in carbon disulfide should be put in from five to ten gallons of water for best results. The solution should then be sprayed on the plants to be treated. The concentrated mixture shows the Brownian movement very well under the microscope. It is probable that this bombardment effect changes the arrangement of the genes in the chromosomes. Polyploid forms are common. The somatic chromosome number can be changed by such treatment. The accompanying photographs show some of the results obtained.

With dogwood the change was from a simple leaf to a compound leaf. In potato, variegated leaves were obtained. Peanuts produced four peanuts per pod instead of the usual number.

Pansies produced ruffled flowers instead of the normal type. Tomatoes were produced with part of the carpels seedless when the plants were treated lightly. Plants given excessive treatment produced small, seedy fruit and the stems of the plants were greatly thickened. Carrots produced additional divisions of the leaf at the midrib of the leaf. In gourd, two types of gourd were produced from the same vine. Parts of the vine assumed various polyploid forms as shown by a fusion of parts in the stems and flowers. In crab apple double flowers were produced by pruning and chemical treatment, but the effect was not repeated the following year when the flowers were normal. With asparagus a height of nine feet was reached while the stems were sometimes flattened and the number of branches were sometimes doubled. Phlox produced several kinds of dwarf plants of the perennial phlox, while the phlox, Drummondi, produced stems several feet in length and bloomed freely. Jerusalem artichoke produced seed and grew to a height of from eight to ten feet. Russian sunflower was dwarfted to several feet in height and produced no seed when excessive treatment was given. Catnip produced stems of about twice normal width. Fuller's tease produced dwarf growth. Tulips produced branched stems. *Aristolochia serpentaria* showed an increase in height.

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Certain Condensations of Polyamines and Polyfunctional Compounds*

JOHN W. SCHICK with ED. F. DEGERING, Purdue University

The purpose of this investigation was to study the reactions of diamines and other polyamines with such polyfunctional compounds as 2,2′-dichloroethyl ether, 1,4-dibromo-2-butene, chloroacetyl chloride and silicon tetrachloride. The results from such condensations have yielded fiber producing compounds, rubber-like products, and resins.

Experimental

Hexamethylenediamine and 2,2′-dichloroethyl ether:

Eighty-seven grams of hexamethylenediamine (0.75 mole), dissolved in 100 ml. of 50% ethyl alcohol, was placed in a three-necked flask equipped with a dropping funnel, condenser, and a mechanical stirrer. One hundred and eight grams of 2,2′-dichloroethyl ether (0.75 mole) in 100 ml. of ethyl alcohol was added dropwise with continued stirring and gentle heating. After the complete addition (2½ hours), vigorous stirring and refluxing were continued for 7 hours. The reaction product, when cooled, could be pulled into fibers. The alcoholic solution was evaporated and the product became solid (m.p. 159°C.). When the solid was heated on a steam cone, it softened sufficiently so that it could be drawn into fibers. The fibers, however, were somewhat brittle and soluble in water.

When pyridine and ethyl alcohol were used as solvents for the condensation, a viscous, orange-brown product was obtained which could be drawn into fibers 10 feet long before breaking.

Hexamethylenediamine and 1,4-dibromo-2-butene:

Fifty-four grams of 1,4-dibromo-2-butene in 100 g. of dibutyl ether was added dropwise over a period of several hours to a refluxing solution of 38 g. of hexamethylenediamine in 100 g. of dibutyl ether with vigorous stirring. A gummy precipitate began to form and it increased as the 1,4-dibromo-2-butene solution was added. When the addition was almost completed, the solution became difficult to stir. The product was filtered and dried. The product had no sharp melting point but decomposed on heating. It was insoluble in water, benzene, chloroform, and pyridine and only slightly soluble in hydrochloric acid. A sample of the product, when placed in a hydraulic press at 5000 lbs./sq. in. and 150°C., yielded a disc which was slightly pliable. It lacked the strength of the common thermosetting plastics.

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* This is an abstract of a portion of a thesis submitted to the faculty of Purdue University in partial fulfillment of the requirements for the Doctor of Philosophy degree by John W. Schick.

Hexamethylenediamine and chloroacetyl chloride:

Twenty-nine grams of chloroacetyl chloride (0.25 mole) in 100 g. of dibutyl ether was added dropwise over a period of several hours to 29 g. of hexamethylenediamine (0.25 mole) in 100 g. of dibutyl ether under reflux. As the addition was continued, a precipitate began to cling to the sides of the flask and stirring became difficult. When the product began to darken, further heating was discontinued. The solution was cooled and the solid product was filtered. The product was suspended in 100 ml. of a 10% caustic solution and vigorously stirred. The suspended product was filtered and as much of the aqueous solution as possible was pressed out and the residue was washed with acetone and air dried. The product had the appearance of sponge rubber. It had a slight resiliency and a certain toughness to stretching. It was insoluble in water, pyridine, carbon disulfide, petroleum ether, glacial acetic acid, ethanolamine, tetraethylenepentamine, 2-nitropropane-butanol mixture, acetone, alcohol and ether. It was soluble in formamide. Suspension of the product in acetone and then extrusion resulted in a fiber with slight resiliency.

1,3-Diaminobutane and silicon tetrachloride:

One gram of silicon tetrachloride was added dropwise to one gram of 1,3-diaminobutane with vigorous stirring. The reaction was violent. The solution turned orange in color and became very viscous. When the product was cooled, it became a clear glassy resin. The product could be drawn into fibers when warmed to the softening point. The fibers, however, were brittle and very hygroscopic.

Tetraethylenepentamine and silicon tetrachloride:

Two grams of silicon tetrachloride was added dropwise to two grams of tetraethylenepentamine with vigorous stirring. The solution became viscous and formed a putty-like material. The putty could be bounced, but it did not show any flattened surfaces from the violent contacts.

A Rapid Method for the Estimation of Alcohols

HOWARD BURKETT, DePauw University

In connection with another research problem it became necessary to estimate the quantity of methanol present. Since many samples were to be analysed, it was desirable that the method be as rapid as possible. Methods reported in the literature for the determination of alcohols are all based upon the reaction of the alcohol with acetic anhydride or acetyl chloride, followed by hydrolysis of the excess reagent, according to the following equations:

$$ROH + CH_3COCl \rightarrow CH_3COOR + HCl$$
$$CH_3COCl + H_2O \rightarrow CH_3COOH + HCl$$

The difference in titre between a blank and a determination is a direct measure of the amount of an alcohol present.

Reported methods (1) were for various reasons considered to be unsatisfactory. Some of them were required two to twenty-four hours for each determination. Some required a large volume of solvent. One (2) required only twenty minutes for the reaction with the acetyl chloride, without solvent, to be completed, but this one required dry ice, which was not readily available to the author.

The method finally employed made use of pure acetyl chloride and simple, readily-available equipment. The reaction was carried out in a 20-ml. bottle and the reagents were introduced through a tight-fitting stopper. Stoppers of various materials were tried. All, including neoprene, rubber and tygon, absorbed acetyl chloride to a certain extent. Rubber seemed to be the least objectionable in this respect, but satisfactory results depended upon the use of as small a stopper as possible and the control of the time of contact with the stopper. With suitable care check results of within ±0.3% were obtained.

Acknowledgment.—The author thanks Commercial Solvents Corporation for the support which made this work possible.

Experimental

Numerous preliminary experiments are, of course, omitted.

Equipment.—A 1-ml. tuberculin syringe, a 10-ml. syringe, two ⅝-inch, 25-gauge hypodermic needles, two 20-ml. bottles[1] with ¼-inch openings at the neck and a supply of ¼-inch rubber stopples[2].

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[1] The bottles used in this work had contained Eli Lilly and Company Physiological Salt Solution.

[2] Furnished by Commercial Solvents Corporation.

Procedure.—Two determinations were performed simultaneously. Each bottle was handled as follows: About 0.3 ml. of acetyl chloride was placed in the bottle and the stopple inserted. The bottle was shaken and let stand for five minutes[3]. The stopple was removed and the bottle half-filled with water. The bottle was shaken with the stopple in place; then the contents emptied. The bottle was filled with water, one-half poured out; then shaken with the stopple in place and emptied. It was then rinsed three times with small amounts of acetone and dried with a current of air. The stopples were placed in a small beaker and rinsed three times with acetone and air-dried for about five minutes. The stopple was inserted and fastened tightly. Using the tuberculin syringe, exactly 0.300 ml. of acetyl chloride was introduced through the stopple. In order to avoid parallax a piece of paper was glued onto the syringe opposite the 0.300 graduation. The bottle was shaken and let stand for five minutes. By means of the 10-ml. syringe, about 10 ml. of water was injected into the bottle and the bottle was shaken with the needle in place. About 11 ml. of air was withdrawn from the bottle into the syringe, which was then removed from the bottle. The stopple was removed and the contents of the bottle were poured into an Erlenmeyer flask. The bottle was filled with water, one-half emptied into the Erlenmeyer, the bottle shaken with the stopple in place and the remaining water poured into the Erlenmeyer. The contents of the Erlenmeyer were titrated with standardized alkali, using phenolphthalien indicator. This is the blank titration.

The bottles and stopples were rinsed and dried as described above and used for an actual determination, the only difference in procedure being that a weighed sample, sealed in a small, thin-walled glass bulb, was placed in the bottle before the stopple was inserted and that the glass bulb was broken by shaking after the addition of the acetyl chloride. If a series of determinations is interrupted for more than a few minutes, it is necessary to pretreat the rubber stopples again with acetyl chloride before continuing. Each day a new blank should be run.

Results.—Table I shows a series of consecutive determinations, except that the pure methanol was run along with a different series at a different time.

Summary

A procedure is described for the determination of methanol, using acetyl chloride as the reagent. The reagent which does not enter into ester-formation is hydrolyzed and titrated with standardized alkali. A 20-ml. bottle is used as the reaction vessel and the reagent is introduced quantitatively, by means of a syringe, through a rubber stopple in the bottle.

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[3] If the stopples were not subject to about the normal exposure to acetyl chloride before starting, the first determination would give a low value.

TABLE I.

Material	Sample Weight	Titre N=.2618	Blank less Titre	Percent Methanol
	Blank	32.96		
	Blank	33.04		
	Av.	33.00		
4	.1345	31.80	1.20	8.0
4	.1525	31.69	1.31	7.6
7	.1391	29.72	3.28	21.0
7	.1779	28.82	4.18	20.9
8	.1266	27.50	5.50	38.6
8	.1259	27.58	5.42	38.2
9	.1103	25.74	7.26	58.6
9	.1327	24.47	8.53	57.1
	Blank	32.92		
	Blank	32.96		
	Av.	32.94		
Methanol	.0986	21.88	11.07	99.8

References

1. A list of references appears in an article by Petersen, J. W. Hedberg, K. W. and Christensen, B. E., Ind. Eng. Chem. Anal. Ed., **15**, 225 (1943), and in the following reference.

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Oxidations with Selenium Dioxide

D. J. Cook, R. W. Sears, and Darrel Dock, DePauw University

Selenium dioxide has been used as a selective oxidizing agent for activated methyl groups in many different types of compounds (1). Most frequently the oxidation reaction is performed in some inert solvent such as ethyl alcohol or xylene. It has been found that nitrogen heterocyclic compounds of the type 1,4-dimethylcarbostyril and 5-keto-7-methyljuloline were best oxidized to the aldehyde when selenium dioxide was added to the fused substance over a temperature range of 145-175°.

The oxidation of 1,4-dimethylcarbostyril to the 1-methyl-4-carbostyrilcarboxaldehyde has already been reported (2). It has been found that the yield of this preparation can be increased from 70% to 95-98% by increasing the size of the reaction mixture from 0.11 mole of the 1,4-dimethylcarbostyril to 0.22 mole or more of the carbostyril. The increased batch size apparently gives better mixing and the oxidation can be carried almost to completion.

The oxidation of three other compounds, 1-ethyl-4-methyl-carbostyril, 1-benzyl-4-methylcarbostyril and 5-keto-7-methyljuloline by an analogous method gave 1-ethyl-4-formylcarbostyril, 1-benzyl-4-formylcarbostyril and 7-formyl-5-ketojuloline.

Experimental

1,4-Dimethylcarbostyril, 1-ethyl-4-methylcarbostyril and 1-benzyl-4-methylcarbostyril were prepared by a method described by Kaslow and Cook (3). Reissert has reported the preparation of 5-keto-7-methyljuloline by the action of ethyl acetoacetate on tetrahydroquinoline (4). We have improved this preparation by the use of diketene with tetrahydroquinoline. The selenium dioxide was prepared by the action of nitric acid on selenium and purified by immediate sublimation.

1-Methyl-4-carbostyrilcarboxaldehyde.—In a 500 ml., three-necked, round-bottomed flask equipped with an air condenser and mechanical stirrer was placed 38.0 g. (0.22 mole) of 1,4-dimethylcarbostyril. The flask was heated in an oil-bath to 150°. To the fused material 28 g. (0.252 mole) of selenium dioxide was added gradually over a period of thirty minutes. During this time stirring was continuous and the temperature was allowed to rise to 175°. The fused mass was maintained at this temperature with stirring for forty-five minutes or until the mass solidified. When cool, the mixture was ground to a powder and extracted twice with 400 ml. of boiling benzene and thee times with 200 ml. of boiling benzene. The combined extracts were filtered, evaporated to about 600 ml. and cooled in the refrigerator. Yellow needles of 1-methyl-

4-carbostyrilcarboxaldehyde were obtained which melted at 179-180°. Evaporation of the filtrate to about 300 ml. gave a small additional yield. The total weight of product was 40.7 g. (98%). An alternate method of extraction can be used by means of a large Soxhlet extractor with about 600 ml. of benzene used as the solvent.

1-Ethyl-4-formylcarbostyril.—In a manner analogous to the preparation of 1-methyl-4-carbostyrilcarboxaldehyde, 19g. (0.10 mole) of 1-ethyl-4-methylcarbostyril was treated with 13.9 g. (0.125 mole) of selenium dioxide. The reaction mass solidified on cooling and was then extracted with two portions of 200 ml. of boiling benzene and four portions of 100 ml. of boiling benzene. The combined extracts were evaporated to 400 ml. and orange-brown needles of the aldehyde crystallized. The weight was 19.8 g. (97%). The product after recrystallization from benzene melted at 117.5-119°.

Anal. Calcd. for $C_{12}H_{13}NO_2$:	N, 6.96
Found:	N, 7.41

The 2,4-dinitrophenylhydrazone was prepared and found to melt at approx. 315-320° (dec.).

1-Benzyl-4-formylcarbostyril.—In a like manner 20.0 g. (0.083 mole) of 1-benzyl-4-methylcarbostyril was oxidized with 10.5 g. (0.094 mole) of selenium dioxide. The reaction mass when extracted with boiling benzene, evaporated and allowed to cool gave yellow needles weighing 11.5 g. (56%). The m.p. of the crude product was 159-160°. A 2 g. sample was recrystallized from 20 ml. of benzene. The m.p. was 161.5-162.5°.

Anal. Calcd. for $C_{17}H_{13}NO_2$:	N, 5.32
Found:	N, 5.03

The 2,4-dinitrophenylhydrazone was prepared and found to melt at 253-255° (dec.).

5-Keto-7-methyljuloline.—In a 250 ml., three-necked flask equipped with a mechanical stirrer, reflux condenser and dropping funnel was placed 20 g. (0.150 mole) of 1,2,3,4-tetrahydroquinoline and 50 ml. of benzene. The solution was heated to reflux on a steam-bath and 12.8 g. (0.188 mole) of diketene was added dropwise. The mixture was then allowed to reflux for four hours. At the end of this time the benzene was drawn off under reduced pressure. The red oil which remained was added in 2 ml. portions to 20 ml. of concentrated sulfuric acid at such a rate that the temperature was held between 100-110°. This mixture was heated on a steam-bath for 10-15 minutes. The sulfuric acid solution was then poured into 150 ml. of ice water and neutralized with 15-16 g. of solid sodium hydroxide. A tan colored, solid, product precipitated which, when dried, weighed 21.2 g. (73%). This material, when recrystallized from benzene-petroleum ether, melted at 130.5-131.5°. Reissert reported a melting point of 129.8°.(4)

Anal. Calcd. for $C_{13}H_{13}NO_2$:	N, 7.03
Found:	N, 6.79

7-Formyl-5-ketojuloline.—In a manner which has been described for the preparation of 1-methyl-4-carbostyrilcarboxaldehyde, 9 g. (0.045 mole) of 5-keto-7-methyljuloline was oxidized with 5.2 g. (0.047 mole) of selenium dioxide. The residual mass was extracted three times with 200 ml. of boiling benzene, filtered and the combined extracts evaporated to about 200 ml. Ten to fifteen milliliters of petroleum ether was added to the benzene solution and, upon cooling, yellow crystals formed. The product weighed 8.2 g. (84%) and when recrystallized from benzene gave a melting point of 149-150°.

Anal. Calcd. for $C_{13}H_{11}NO_2$:	N, 6.57
Found:	N, 6.28

Summary

Additional studies of the oxidation of 1,4-dimethylcarbostyril with selenium dioxide have given an increase in the yield of 1-methyl-4-carbostyrilcarboxaldehyde from 70% to 98%.

Several new aldehydes, 1-ethyl-4-formylcarbostyril, 1-benzyl-4-formylcarbostyril and 7-formyl-5-ketojuloline have been prepared.

The preparation of 5-keto-7-methyljuloline has been improved over that of the method of Reissert by the use of diketene with tetrahydroquinoline.

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Some p-Nitro- and p-Aminobenzoates of Sulfur-containing Alcohols[1]

E. CAMPAIGNE and PHILIP R. FERGUSON, Indiana University

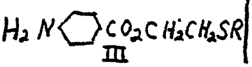
The effect of replacing oxygen by sulfur atoms in physiologically active compounds has been frequently studied, as in alkamine esters of furoic and thenoic acids (1), the alkamine esters of p-aminothiolbenzoic acid (2, 3) and the alkamine esters of p-methylmercaptobenzoic acid (4). However, no examples have been reported in which the effect of replacing the nitrogen atom by sulfur has been determined. Since sulfur lies between oxygen and nitrogen in its ability to form onium salts, it may be able to replace nitrogen in certain physiologically active compounds. For instance, acetylcholine (I) exerts powerful physiological effects,

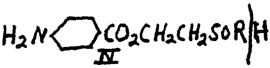
$$CH_3COOCH_2CH_2N^+(CH_3)_3 \qquad CH_3COOCH_2CH_2S^+(CH_3)_2$$

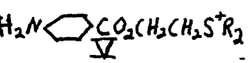
I II

but the activity of the β-acetoxyethyl dimethylsulfonium compound (II) has not been determined.

To test this hypothesis, an attempt was made to prepare the p-aminobenzoates of some alkylmercaptoethanols (III), alkylsulfonylethanols (IV) and dialkylsulfoniumethanol salts (V).


III


IV


V

These were to be tested as local anesthetics, comparing their activity to procaine. However, only the sulfonyl esters (IV) were prepared in the pure form, the other two types being highly unstable and difficult to purify. The sulfonyl esters were apparently completely devoid of local anesthetic activity. Impure β-ethylmercaptoethyl p-aminobenzoate and β-n-butylmercaptoethyl p-aminobenzoate were qualitatively active by tongue test, but have not been obtained in pure form for quantitative testing.

The sulfonyl esters were prepared by esterifying the β-alkylmercaptoethanols with p-nitrobenzoyl chloride, oxidizing the ester to the sulfone, and catalytically reducing the nitro group. This procedure gave pure products in high yield. The intermediate alkylmercaptoethyl p-nitrobenzoates could not be purified, as they were oils which decomposed on distillation at reduced pressure. The p-nitrosulfones derived from these esters were crystalline and analyzed correctly, showing that the sulfide ester had been obtained.

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[1] Abstracted from a thesis submitted by Philip R. Ferguson to the faculty of Indiana University in partial fulfillment of the requirements for the degree Master of Arts in the Department of Chemistry, October, 1948.

[2] Present Address: Chemistry Department, University of North Carolina, Chapel Hill.

Two methods were tried in an attempt to prepare pure β-alkylmercaptoethyl p-aminobenzoates. Reduction of the impure p-nitrosulfides was unsuccessful. Chemical reduction with tin or iron in hydrochloric acid led to complexes which were intractable. Low-pressure catalytic reduction using palladium chloride on charcoal resulted in hydrogenolysis of the sulfide linkage, so that ethyl p-aminobenzoate and the alkylmercaptan were obtained. The mercaptans were not isolated, but were evident by their odor and by strong nitroprusside tests. Coupling potassium alkylmercaptides with β-chloroethyl p-aminobenzoate in alcohol solution produced crude oils or low-melting solids which were extremely unstable, and only amorphous products which contained less than the calculated amount of sulfur were obtained.

Treatment of these impure p-aminosulfides with alkyl halides formed crude salts which were also unstable and were not further investigated. It would be of interest to determine whether the sulfide or the amine group coupled preferentially in this reaction.

Experimental

β-Ethylsulfonylethyl p-Nitrobenzoate:

A solution of 40.6 g. (0.38 mole) of β-ethylmercaptoethanol, prepared by the method of Fromm and Jorg (5), and an equimolar amount of p-nitrobenzoyl chloride (75 g.) in ether was shaken, and 35 g. of pyridine was added dropwise. The pyridine hydrochloride which precipitated was removed by filtration, and the ether removed under reduced pressure. The resulting yellow, viscous oil weighed 83 g., equivalent to 85% yield of pure product. A solution of 15 g. (0.06 mole) of the crude p-nitrosulfide was dissolved in 100 ml. of glacial acetic acid, and 40 ml. of 30% hydrogen peroxide added. After standing for 48 hours at room temperature, the solution was diluted with cold water, and the crystals which separated were filtered and dried. After recrystallization from ethanol, 16.6 g. (98%) of glistening white plates which melted at 110-111° were obtained.

Anal: Calcd. for $C_{11}H_{13}O_6NS$; %S, 11.17. Found, %S, 11.33

β-Ethylsulfonylethyl p-Aminobenzoate:

A 10 g. sample (0.035 mole) of β-ethylsulfonylethyl p-nitrobenzoate was dissolved in 150 ml. of ethanol and 0.2 g. of Adams platinum oxide catalyst (6) added to the solution in a pressure bottle. The bottle was placed in a low-pressure hydrogenation apparatus and shaken until a pressure drop of 9 lbs. of hydrogen had occurred. The catalyst was removed by filtration, and the ethanol solution distilled. The amine was obtained by dilution with water, and recrystallized from ethanol-water mixture. It was obtained as white crystals, soluble in acid and melting at 115-116°.

Anal: Calcd. for $C_{11}H_{15}O_4NS$; %S, 12.45. Found; %S, 12.69.

β-n-Butyl sulfonylethyl p-Nitrobenzoate:

Since the reaction of ethylene oxide and butyl mercaptan gave greatly reduced yields of β-n-butylmercaptoethanol, crude β-n-butylmercaptoethyl p-nitrobenzoate was prepared in a different way. A solution of potassium butylmercaptide was prepared by dissolving 4 g. (0.44 mole) of butylmercaptan in 20 ml. of ethanol containing 2.5 g. (0.044 mole) of potassium hydroxide. To this was added a solution of 10 g. (0.044 mole) of β-chloroethyl p-nitrobenzoate (7) in 30 ml. of ethanol. After standing at room temperature for 24 hours, the solution was diluted with water and extracted with ether. After drying, the ether was removed and 8.4 g. (67%) of a yellow oil was obtained. This crude sulfide was oxidized in theoretical yield to the sulfone, which was obtained in white plates, melting at 63-64°.

Anal: Calcd. for $C_{13}H_{17}O_6NS$; %S, 10.16. Found; %S, 9.90.

β-n-Butylsulfonylethyl p-Aminobenzoate:

Catalytic reduction of the purified β-n-butylsulfonylethyl p-nitrobenzoate proceeded smoothly and quantitatively, yielding β-n-butylsulfonylethyl p-aminobenzoate in white crystals which melted at 93-93.5° after purification.

Anal: Calcd. for $C_{13}H_{19}O_4NS$; %S, 11.23. Found; %S, 11.61.

Summary

The p-nitro- and p-aminobenzoates of β-ethylsulfonylethanol and β-n-butylsulfonylethanol have been prepared and characterized. These esters are apparently devoid of local anesthetic action.

Efforts to obtain the corresponding esters of β-ethylmercaptoethanol and β-n-butylmercaptoethanol were not successful.

References

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ENTOMOLOGY

Chairman: W. P. ALLYN, Indiana University

Edward Kintner, Manchester College, was elected chairman for 1949.

ABSTRACTS

Anax longpipes Hagen (Odonata; Aeshnidae), an Atlantic Coastal Species in Indiana. B. ELWOOD MONTGOMERY, Purdue University.—*Anax longpipes* is apparently common in the Atlantic coastal area from Massachusetts to Brazil, although relatively few specimens are ever captured. There are several records of this species in the region west of the Appalachian Mountains, chiefly from Ohio. However, all but one of these records are based upon sight identification of the insect in flight. The species was added to the Indiana list from such a record in Clark County. In early July, 1948, a specimen was taken at Scales Lake State Forest in Warrick County.

The Describers of Odonata. B. ELWOOD MONTGOMERY, Purdue University.—The authors of the names, proposed for species, sub-species and categories of lower rank in the Odonata have been compiled from the Williamson-Montgomery index to the literature of the Odonata.

Linnaeus described 22 species of Odonata in the 10th edition of the Systema Naturae in 1758. Since that time about 183 authors have described or otherwise proposed names for species and groups of lower rank in the Odonata. Of these, about 60 have named but one species, about 15 two species and about 20 three or four species. The "Father of Odonatology," Edmund de Selys-Longchamps, is the author of 1121 names, more than one-fifth of those in the index. Four of these authors were native to the state or did much of their work in Indiana.

Insecticidal Control of the Clover Root Borer

Hylastinus obscurus (Marsh.)[1]

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Agriculture, Agricultural Research Administration,
Bureau of Entomology & Plant Quarantine.

One of the most serious insect pests of red clover in Ohio and Indiana is a small beetle called the clover root borer, *Hylastinus obscurus* (Marsh.), belonging to the family Scolytidae. The principal characteristic of clover infested by this insect is the failure of the second-year plants to recover after the first hay crop is removed in June. Second growth is weak, and blossoms are sparse and scattered. When infestations are heavy, many plants make no second growth and die.

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[1] Bur. Ent. and P. Q. MS. 9168.

[2] Resigned June 30, 1948; now Associate in Entomology, Purdue University Agricultural Experiment Station.

The adult stage is reached in late July and August. Migration to new clover may occur in the fall and is usually completed in April and Early May of the following year. The females burrow into the crown of the clover plant and lay their eggs in the galleries late in April and in May. Upon hatching the larvae burrow and feed in the roots. Pupation occurs in these burrows in July.

Since this insect is inside the clover roots during the entire period of development, control is difficult. Plowing severely infested fields in July or after second harvest in August to destroy the larvae and pupae does not permit the growing of a seed crop. Chemical control of the insect in the roots is difficult, as tunnel openings are small and chemicals sufficiently toxic to destroy the insects are liable to be injurious to the clover plant also. Experiments are underway to test various organic insecticides mixed with the soil before the clover is planted, but no data of significant value have yet been obtained. The possible use of any of these insecticides for soil treatments, particularly benzene hexachloride, may be limited by their effect on plant growth or flavor of crops grown in the treated soil, as determined by further investigations.

During 1947 some preliminary experiments were conducted at Croton, Ohio, to prevent infestation of newly seeded red clover by the use of organic insecticides having residual toxicity. Three insecticides—DDT, chlordane, and benzene hexachloride—were applied to the plants and soil surface with a 36-inch hand fertilizer applicator. DDT and chlordane were applied as 1% dusts at the rate of 5 pounds of active ingredient per acre, and benzene hexachloride as a 0.25% gamma dust at 1.25 pounds of the gamma isomer per acre. Examinations by dissection of 15 to 17 roots per plot from each of the four replications gave the results from the May 7, 1948 application as follows: 3.6 borers per root in the untreated plots, 2.5 borers per root in the plots treated with DDT, 0.2 borers per root in the plots treated with chlordane, and no borers per root in the plots treated with benzene hexachloride.

Oriental Fruit Moth Control by Spraying

C. EDW. MARSHALL, Purdue Agricultural Exp. Station

The Oriental fruit moth entered Indiana in the late 20's, and spread rapidly into all the peach growing sections of the State. As early as 1930 infestations had begun to be so heavy that the growing of this crop became hazardous in many sections. Within the next few years it was suggested by the experiment station itself that varieties of peaches grown and ripening later than midseason Elberta be dispensed with to prevent crop losses, and to eliminate varieties which would permit the development of late broods of the moth permitting it to successfully overwinter. Following this, such late varieties as Fleener, White Heath, and Williams Favorite and so-called "pickling peaches" passed out of the picture. Between 1932 and 1936 it was not uncommon for such late varieties, where they had not been destroyed, to be 95 per cent infested by the Oriental fruit moth by ripening time.

Not only were the late varieties heavily infested, but in many instances midseason Elberta carried from 35 to 65 percent infestation in the fruit at harvest time. This led to the harvesting and sale of fruit that was hard ripe, and of rather poor quality in order that the fruit could be picked and sold before the full fourth brood of the Oriental fruit moth had a chance to attack.

In Indiana, three methods of control of the insect were attempted, each with a measure of success, but only one of them outstanding. These were by parasite introduction, mechanical control, and by spraying. Immediately after the pest became well established in Indiana, and as a result of research work done in New Jersey and other eastern states before the arrival of the insect in this state, it was possible to attempt control by the introduction of parasites and predators. This work was cooperative with the United States Department of Agriculture. Approximately half a dozen species of parasitic hymenopterus insects were introduced. Of the several species of hymenoptera colonized only one *Macracentrus ancylivorus*, gave promise of being of economic importance. Scores of liberations were made, and these scattered over the entire state. Liberations made during the summer of one year were followed by the recovery collections and rearings the next year. In this way it was found that in the sandy and low lying or level sections this parasite became established very readily, and it soon brought the Oriental fruit moth attack on peaches down to 20 percent or less. This did not take place, however, in the knob or ridge orchard localities having heavy clay soils. Repeated attempts to recover the parasites, after colonization a year earlier, failed. This then is where the work of introducing parasites finally stood. The reason why *Macracentrus ancylivorus* was unable to establish itself in orchards with heavy soils was never learned.

A few years after the parasite work began, an effort was made to control the Oriental fruit moth mechanically. The larvae of the first three broods of this species attack and feed on the succulent, rapidly growing twigs of the peaches. It requires fifteen to eighteen days, according to the temperature, for them to become full fed. It was surmised control could be obtained by clipping off the wilted or infested twigs. First an attempt was made to clip off all the infested twigs about twice during the larval life of fifteen to eighteen days. This was found to be insufficient so, in later studies, the clipping was done every five days. If such intervals are maintained in the clipping, it was found that on an average one larvae was destroyed to every two twigs clipped. The work was finally carried to the 90 odd acre Wood-Gamble orchard at Sullivan to learn whether or not it was practicable on a commercial scale. It was found to offer a great deal of promise in control though the high old trees in this orchard made the labor cost high, and the height of the trees made it difficult to see newly wilted twigs.

For this reason an orchard of Gage Elberta peaches was grown low (no tree more than nine feet high) in order that the infested twigs would be more accessible. To further reduce the cost of the work below that expended when ladders were used, stilts were substituted. By growing the trees low, and by using stilts instead of ladders the labor cost of the operation was reduced a third. Not only were the infested twigs removed, but with the numerous times the trees were inspected it was not difficult to remove practically all defective fruits.

As the program was finally perfected, the Oriental fruit moth could easily be held to less than 15 percent infestation if the clippings was continued through the third brood. In addition the curculio was brought to a standstill inasmuch as the defective peaches were removed whenever they were noticed during the clipping operation. Most important, brown rot, which follows with proportional severity the attacks of curculio and Oriental fruit moth, ceased to be a threat. All in all then the clipping operation proved to be a good and practical operation in peach plantings grown to facilitate the practice. Its adoption, however, was limited to sections where Macracentrus ancylivorus could not be successfully colonized.

During the intervening period between the introduction of the Oriental fruit moth in Indiana, and the advent of DDT every spray material or combination of dust and spray that seemed to offer promise in control was given a trial on plot tests. The nearest approach to success was through the use of a five percent oil-sulphur dust developed in Illinois. Though the claim for the material was that it would, if used four or five times beginning a month before harvest and at five day intervals, control up to 50 percent of the Oriental fruit moth larvae, this was not enough. In south central Indiana the attack too often reached 60 percent, and with 50 percent control the loss of peaches to the insect was still 30 percent which is too high.

After the advent of DDT, control seemed rather simple as the result of our having worked out the clipping program so completely. We knew that the larvae spend fifteen to eighteen days in the twigs, that in that time they go from one twig to another and in all each larvae attacks an average of five twigs. We also knew that it is the fourth brood that enters the Gage Elberta variety with which we were working. Since the succulent peach twigs grow very rapidly it is difficult to keep them covered with spray material. It was early decided that to prevent attack the trees would need to be sprayed often with the insecticide. Applications of eight ounces of actual DDT were put on every five days beginning just before the first hatch of the fourth brood of larvae. This done the program went well from the standpoint of control and application. The control of the insect was very satisfactory (2.5 percent wormy as compared to an infestation of 23.7 percent in the neighboring orchard).

Such a program when presented to growers and entomologists led to considerable discussion for it was believed that as a result of four or five applications of DDT so late in the season the residue of DDT would be above the tolerance set by the Food and Drug Administration. No analysis of DDT in the harvested fruit had been made between the last application and harvest so there could be no certainty as to this point. However, in order to reduce the possibility of such being the case, the 1948 plot spray treatments were worked out keeping this in mind.

Instead of directing the DDT spray program against the fourth brood of larvae of the Oriental fruit moth it was applied to control of the third brood. This left almost a month between the last DDT spray and harvest. Such a program worked more successfully than any used earlier, and the harvest infestation was .025 percent Oriental fruit moth this year. In the first place it controls the Oriental fruit moth after late July thereby giving the twigs on the trees a chance to get considerably more growth before fall without being attacked by the Oriental fruit moth as was usually the case. This past season especially was growth needed for the second brood had attacked practically every succulent twig. In addition, from observations made to date, two and possibly only one, DDT spray in addition to those for Oriental fruit moth control may be necessary for the control of the peach borer, *Sanninoidea exitiosa* (Say). The program aids indirectly in brown rot control, and it is very effective against the second generation attack of the plum curculio. If no DDT has been applied earlier in the season it is probable that a serious spider mite problem will not develop for in the two years of the study there has been no serious mite population built up. The program fits well with the use of benzene hexachloride for the control of curculio, and with the use of chlordane for the control of insects causing cat-facing or for curculio.

One disadvantage which will be voiced against this kind of control is that it is a spray instead of a dust program. However, it may be that further study will lead to a satisfactory dust program. Meanwhile, and for the first time since the introduction of the Oriental fruit moth into Indiana, the latest ripening varieties of peaches that can be grown in this state may be planted with certainty that this pest, for a time uncontrollable, can be held in almost complete check. Now again we are growing "pickling peaches" such as Salberta, Fleener, White Heath, and Autumn, the latter a new variety developed in New York and one ripening just before freezing weather.

The Introduction of Exotic Species of European Corn Borer Parasites in Indiana

M. CURTIS WILSON

Purdue University Agricultural Experiment Station

It has long been known that the natural enemies of our major pests play a significant role in control. In an attempt to increase natural control, workers of the Bureau of Entomology and Plant Quarantine studied the biological control of the corn borer in its natural habitat in Europe. Before introducing a species to a new environment it is necessary to ascertain all the facts of its biology. Misjudgment in this matter can be catastrophic. It must be certain before introducing a new species that there will be no way in which it could possibly get out of hand in its new environment. The habits of the insect must be known as well as the climatic and environmental factors which influence its development. Above all the species to be introduced must be specific in its host selection. Yet, it is desirable for the parasite to have a secondary host which is a related species to the primary host so that it may survive through seasons when the primary host population is low.

After determining those natural enemies which were specific to the corn borer in Europe the more promising species were brought to America and colonized at the federal parasite laboratory in Moorestown, New Jersey. From there they have been distributed to Indiana and other corn borer infested states.

During the past five years the Purdue University Agricultural Experiment Station has received the following species of corn borer parasites for liberation in Indiana: *Lydella grisescens, Macrocentrus gifuensis, Horogenes punctorius,* and *Chelonus annulipes.*

Lydella grisescens R. and D. is a Tachinid fly. Oviposited near borer tunnels, the egg hatches immediately and the young maggot searches out the host larva. It succeeds best against the older instar borers but due to the long preoviposition period, it is necessary to release the adult parasites when the host larvae are very small.

Probably the most easily established of our exotic corn borer parasites this Tachinid fly seems to increase very rapidly and has been known to parasitize the borer to the extent of 50 percent or higher within two or three seasons. It was first introduced in Indiana in Tipton County where it destroyed 30 percent of the corn borers last season. It was found that it had also established itself in a number of other counties and promises to become a factor in the control of the corn borer.

Macrocentrus gifuensis is a polyembryonic species. It deposits its eggs directly within the host larva attacking the younger stages of the borer. From five to forty parasites may be obtained from a single host.

More difficult to establish than *Lydella grisescens* this braconid increases and disperses more slowly during the first few years following establishment. However, in some localities, particularly in Southern New England, it has finally surpassed all other parasites combined. *Macrocentrus* has been extensively released in Indiana but has never been recovered. Colonies released this year were concentrated in the northern counties, LaPorte and Steuben. It is believed that these counties have a cooler season more comparable to that of New England than counties further south. It is hoped that they may gain a foothold there and then gradually work south throughout the state.

Horogenes punctorius, an ichneumonid, attacks the mid-instar borers. It has become established in some localities where other parasites have failed. It was released in Marshall and Jasper counties in Indiana but has not been recovered. When once established it is known to be quite persistent and remarkably stable after reaching equilibrium.

Chelonus annulipes Wesm. is a braconid which first attacks the corn borer in the egg stage. The parasite oviposits in the corn borer egg, but does not kill the borer until it is nearly full grown. It has never become abundant in the United States. In Indiana it was released in Tipton County and has been recovered once. It is believed that it may be effective in some very restricted localities. It is abundant in Europe in only one region, the Po River Valley in Italy.

Parasites have been released in 31 counties as follows: Adams, Benton, Blackford, Boone, Clay, Carroll, Cass, Clinton, Fayette, Fountain, Fulton, Grant, Hamilton, Hendricks, Henry, Jasper, Kosciusko, LaPorte, Marshall, Marion, Miami, Newton, Putnam, Porter, St. Joseph, Switzerland, Tipton, Tippecanoe, Vermillion, Warren, and White.

TABLE I. *Lydella grisescens* Recovery in Indiana in 1947.

County	No. of Collections	No. of Borers Observed	Number Parasitized	Percent Parasitized
Benton	5	57	4	7.0
Blackford	3	30	3	10.0
Clay	2	3	2	66.7
Hamilton	5	38	11	28.9
Henry	5	73	3	4.1
Jasper	19	377	48	12.7
St. Joseph	5	59	4	6.8
Tipton	25	560	168	30.0

When introduced into a new environment, parasites encounter obstacles such as differences in climate, abundance of host, etc., to which they must adapt themselves if they are to survive. To determine the degree of success met by these parasites in establishing themselves a survey was made during the fall of 1947 and another is being planned this fall. Corn borer larvae were collected in the various counties where parasites had been liberated. These were shipped to the Moorestown laboratory where they were processed by placing them in rearing cages to determine the parasites which emerged. Collections were of necessity small in some counties due to the low population of corn borers. *Lydella grisescens* was the only species recovered. The following table shows the number and percent of borers parasitized.

Although the number of parasites recovered was quite low in most of these counties the data are indicative that *Lydella* has become established and should eventually increase and spread over Indiana.

A Simple Larvacide for Ornamental Pools and Spawning Ponds

W. P. ALLYN, Terre Haute, Indiana

An effort has been made to prepare an effective larvacide for ornamental pools and spawning ponds with a minimum of time, equipment, and materials. It has been noted that mosquito larvae, especially the anopheles, inhabit such bodies of water and thrive even in the presence of fish. The Anopheles larvae confine their activities in the main to the surface of the water, and often take refuge among lily pads and other water plants, and escape the feeding range of minnows and other small fish.

Materials and Equipment

The materials used, with the exception of concentrated oil-pyrethrum extract, can be obtained at the corner grocery: kerosene, any good graulated laundry soap, chemical water softener or common bath salts (trisodium phosphate), concentrated oil-pyrethrum extract (pyrethrins 2.0 grams per 100 cc.)*, and water.

No special equipment is needed. A two-gallon granite kettle, a graduate, and a five-gallon kerosene can are adequate.

Preparation of Stock Solution

One hundred grams of granulated soap and 20 grams of water softener (tri-sodium phosphate) are added to three quarts of water and boiled vigorously in the granite kettle until all ingredients are in solution. The solution is then transferred to the five-gallon can.

Immediately while the soap solution is hot, one gallon of kerosene, to which 800 cc. of oil-pyrethrum extract has been added, is poured gradually into the hot water soap solution and the mixture shaken vigorously for five or ten minutes. A very satisfactory emulsion can be obtained within a very few minutes. The stock solution, if kept in a light-proof container and in a reasonably cool place, retains its strength for months.

Application of the Larvacide

One part of the stock solution of larvacide is added to seven parts of warm soft water and applied to the surface of the ornamental pool with an ordinary two-gallon knapsack sprayer.

Mosquito larvae have been observed to succumb readily in the presence of the larvacide, yet no damage to fish or plant life has been noted. The general health and vigor of water cress, lilies, and other water plants seems to improve with the use of the larvacide, perhaps because of the control of other parasitic insect pests.

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* Pyrocide-20, produced by McLaughlin Gormley King Company, Minneapolis, Minnesota, has been found very satisfactory.

GEOLOGY AND GEOGRAPHY

Chairman: FLOY HURLBUT, Ball State Teachers College

Preston McGrain, Indiana Flood Control and Water Commission, was elected chairman for 1949.

ABSTRACTS

On the Outstanding Features of the Great Climatic Cycle, A. V. LOTT, Sellersburg.—Studies of cyclic variations in world climates have revealed the existence of a variation which covers such a long period that it may aptly be called "the great climatic cycle." The last cycle of this series began in Paleozoic time and continued into the recent epoch of earth history.

Variations during the period have ranged from the highly developed system of zonal climates which prevails today to the mild and relatively uniform climates of the middle to late Mesozoic. At the beginning of the cycle in Paleozoic time conditions seem to have been similar to the conditions of today. This was followed by a period of widespread continental glaciation, then by a period of mountain building, then by cool temperate climates which developed into warm temperate and then into climatic uniformity. This was followed by warm temperate which developed into cool temperate conditions, then into mountain building, then into a period of widespread continental glaciation and finally into the climates of today.

The author suggests a possible cause of such variations and explains how each climatic condition may develop.

Trends in the Settlement of Indiana as Indicated by the Voting Residences of Certain Elected Officials, JOHN STRIETELMEIER, Valparaiso University.—The writer is interested in testing 1) whether there is any close correspondence between the distribution of people within a political unit and the distribution of the officials they elect (in this case the governors, senators, and federal representatives elected by the people of Indiana); and 2) whether a series of distribution maps prepared so as to show the cumulative distribution of these officials will disclose any trends in the distribution of the population in general from decade to decade.

He concludes that there is at least a strong tendency for political control to gravitate toward those areas which are numerically strongest and that it is possible to trace with fair clarity the filling up of the state of Indiana by following the movement of its political leaders from decade to decade.

The Present Status and Correlation of the New Albany Shale Flora, J. H. HOSKINS and A. T. CROSS, University of Cincinnati.—The flora represented by petrified wood fragments found in the New Albany black shale of Indiana and in other similar Devonian-Mississippian deposits in Kentucky, Tennessee and Ohio is much more extensive than generally recognized. The most abundant assemblage of these plants is found in the Falling Run member (Upper Sanderson) of the Lower Mississippian rocks as defined by Campbell. Fewer plant fragments are to be found in the Lower Sanderson and the Underwood and Henryville formations above.

The shales containing this flora lie above those bearing the well-known Callixylon Newberryi which has not been found *in situ* in strata below the Upper Blackiston (U. Dev.) in this region. Additional species of Callixylon are found in the Sanderson.

It is believed that the wood fragments, which are now principally phosphatic, and which are found either in phosphate nodules or as isolated pieces intermixed with them, were concentrated in the bottom deposits of a black mud sea over a long period of time, during which little or no inorganic sediments were accumulating. The source of the vegetation represented by the petrified wood is uncertain, but the greatest concentration of material is on the west side of the Cincinnati arch between New Albany, Indiana and Danville, Ky. The fossil wood is progressively less abundant to the east, at least as far as Irvine, Ky., and to the south into Tennessee around the Nashville dome. One specimen has been recovered from the principal nodule zone as far south as Chestnut Mound, Tenn. A few fragments have been found in the nodules and shale of the rocks equivalent to the Lower Sanderson (Gassaway fm.) as far south as Rowena, Ky.

The species represented appear to correlate rather well to those found in similar deposits of presumed near-equivalent age in Europe, but among them are only a few which may be considered as typically Devonian or Mississippian in range.

Geological Features of the Proposed Cagle's Mill Flood Control Reservoir

PRESTON MCGRAIN

Indiana Flood Control and Water Resources Commission*

The purpose of this paper is to describe some of the geological features of the lower portion of Mill Creek valley and to point out the relationship between the geological phenomena exposed and the use of Mill Creek valley as a flood control reservoir. It is not the primary intent of this paper to justify or criticize the selection of this particular site nor to attempt to point out how it fulfills Lippincott's (2), p. 25) requisite conditions for a reservoir site, but rather to describe the unusual physiographic conditions in what is to be the first flood control project of its kind in Indiana. This report is the result of geological investigations made by the writer during the spring and summer of 1948 in order that a permanent record might be made of the features which are currently exposed in that area.

For a number of years the Corps of Engineers, United States Army, has had under consideration a project known as the Cagle's Mill Reservoir on Mill Creek. More recently funds were appropriated by Congress to begin work on this project. Since this is the first such project under construction in Indiana, tremendous interest has been shown by conservationists, engineers, naturalists, scientists, and others.

Cagle's Mill Reservoir is located along Mill Creek in northwestern Owen and southwestern Putnam counties, Indiana (figure 1). The proposed dam site is located near the east side of the resort and recreation area known as Hoosier Highlands, about two and one-half miles southeast of the confluence of Mill Creek with Big Walnut Creek. Together these two streams form Eel River. The name of the proposed dam and reservoir was transferred from a proposed dam site about one mile downstream from the present location, nearer the old Cagle's Mill. The height of the proposed dam is sufficient to impound water during flood times to the upper falls at Cataract at an elevation of 704 feet. A conservation pool will be maintained for recreation purposes at an elevation of 636 feet. This permanent pool will reach from the dam upstream to the foot of Lower Cataract Falls.

Physiographically, the proposed reservoir area lies in the northern portion of the Crawford Upland of southern Indiana, one of the most rugged sections of the state. However, with the exception of the areas immediately adjacent to the major streams the topography is neither as diverse nor as highly dissected as the area farther south. The more

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* Published by permission of the Chief Engineer, Indiana Flood Control and Water Resources Commission.

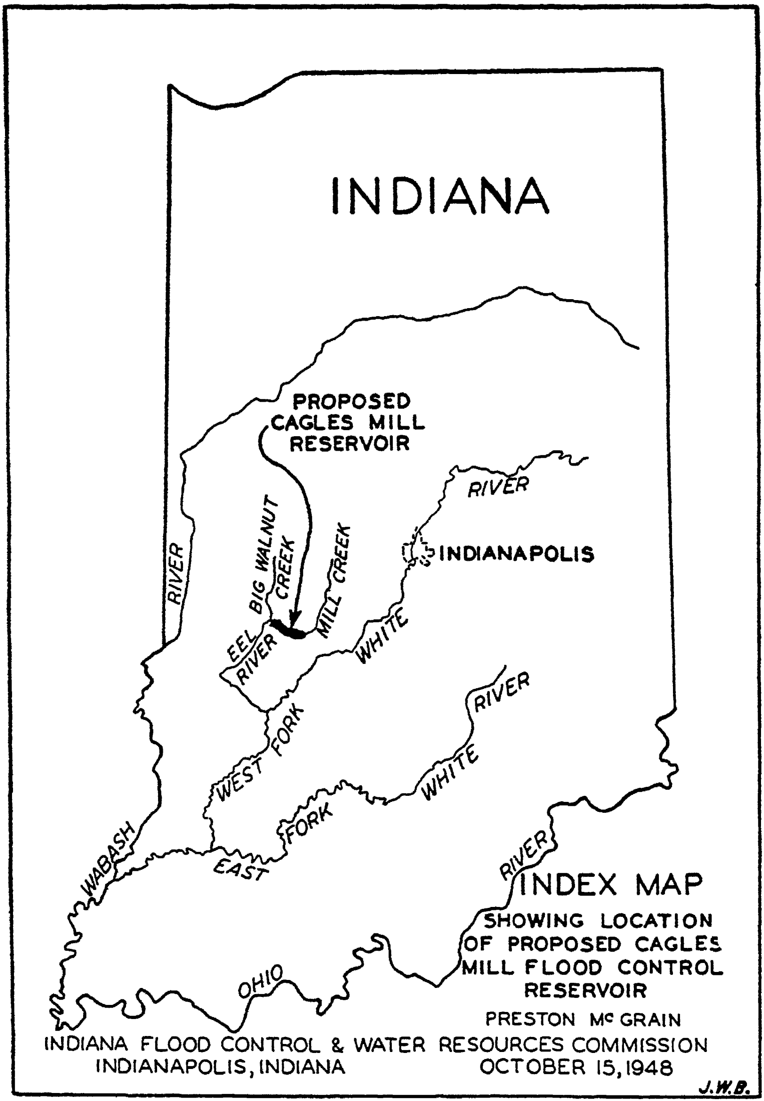


FIG. I

gentle topography of the lower Mill Creek section of the Crawford Upland is the result of the presence of Illinoian glacial drift and the absence of much of the Chester section which thickens southward and thins northward. The highest hills and ridges are capped with Mansfield sandstone of basal Pennsylvanian age and the deeper valleys are generally cut into middle Mississippian limestones. The oldest exposed rocks are cherty limestone strata of St. Louis age which may be found at the lower falls at Cataract.

Associated with the proposed Cagle's Mill reservoir and encompassing a considerable portion of the watershed of Mill Creek are two glacial lakes which occupied portions of Owen, Morgan, Putnam, and Hendricks counties during Illinoian and Wisconsin times. Thornbury (5) proposed the names Lake Quincy and Lake Eminence for these lakes, presented in detail the early literature bearing upon them, and discussed the results of his own detailed studies as to their areal distribution, origin, and ages. The relationship of Lake Quincy, the western most of these lakes, to the Cagle's Mill Reservoir will be discussed in another paragraph.

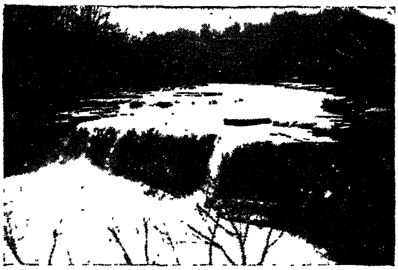


Fig. 2. View of Lower Cataract Falls. The height of the main falls is about 18 feet. Photo by W. T. Powers.

Not only did the glacial lakes attract the attention of the earlier writers but also the two picturesque limestone falls (figure 2) near the village of Cataract, Owen County, have been described and discussed in geological literature on numerous occasions. Thornbury (5), p. 137-140) describes the relation of Cataract Falls to Lake Quincy. More recently Malott (4) presented a detailed study of the stratigraphy of the two falls. The stratigraphic units described and identified by Malott (4) were recognized by the present writer throughout the reservoir area.

Mill Creek rises in western Hendricks County and flows south and southwest across the glacial till and lacustrine plain to Cataract Falls. From Amo in Hendricks County to the top of Upper Cataract Falls, a distance of approximately 35 miles, Mill Creek falls 102 feet or about 3 feet per mile. At Cataract Falls within a distance of a mile, which includes both falls and the connecting rapids, Mill Creek rushes, cascades, and falls about 80 feet from an elevation of 715 feet at the top of the upper falls to an elevation of 635 feet at the foot of the lower falls. From the foot of the lower falls to the proposed dam site, a distance of approximately 8 miles, the drop is but 35 feet or a little over 4 feet per mile. According to planimetric measurements the drainage area of Mill Creek is 375 square miles, 284 of which lie above Hoosier Highlands.

After passing Upper Cataract Falls, Mill Creek encounters a buried bedrock valley which is believed to have been a tributary to the preglacial course of Mill Creek. Here the valley expands greatly in width. Collett ((1), p. 308, Malott ((3), p. 210-211) and ((4), p. 322), and Thornbury ((5), p. 139) recognized the presence of a buried valley in the Mill Creek area but made no attempt to trace it in detail. An excellent exposure of lacustrine deposits was seen in the south bank of a tributary stream in the southwest corner of Section 25, T. 12 N., R. 4 W. The valley narrows again as it approaches the lower Cataract Falls and bedrocks is exposed in the channel and walls of the valley. Here the second bedrock barrier is encountered. From Lower Cataract Falls to the proposed dam site Mill Creek crosses bedrock ridges at numerous points. These exposures vary in expression ranging from small masses barely visible above the water level to hills up to 780 feet in elevation. Near Hoosier Highlands, Mill Creek encounters a bedrock upland mass through which it extends as a gorge for a mile or more. Here the elevation of bedrock on the south side of the creek is 780 feet and on the north side of the creek over 800 feet. The location of the exposures of bedrock and elevations are shown on figure 3. The areas between the partially exposed bedrock ridges and spurs are filled with glacial drift or lacustrine silts or both. Good exposures of these unconsolidated deposits are not common due to rapid weathering, slump, and vegetation and soil coverings. The glacial drift, where exposed, is dominantly till. Boulders and cobbles are present but not abundant. Glacial gravel was observed at three places in abandoned gravel pits. These exposures appear to be parts of a low morainic mass extending in a northwest-southeast direction on the west side of Cagle's Mill reservoir area. The lacustrine deposits consist of thinly laminated calcareous clays, silts, and very fine sands. These sands are described by water well drillers as quick sands. Thornbury ((5), p. 134) traced the lacustrine deposits down the valley of Mill Creek to the village of Cunot in Section 28, T. 12 N., R. 4 W. It was at this point that he placed a morainal dam which caused the ponding of ancient Mill Creek and created glacial Lake Quincy. The present writer has traced the lacustrine deposits still farther downstream thus indicating an early developmental stage of glacial Lake Quincy and a moranial dam somewhat farther downstream than had previously been considered. Excellent exposures of lacustrine silts and sands were observed near the center of the west side of Section 21, T. 12 N., R. 4 W., and in the east bank of a small tributary of Mill Creek in the extreme northwest corner of Section 20, T. 12 N., R. 4 W. The following is a stratigraphic section of the Illinoian deposits observed in the east bank of a small tributary of Mill Creek in the northwest corner of Section 20, T. 12 N., R. 4.W.:

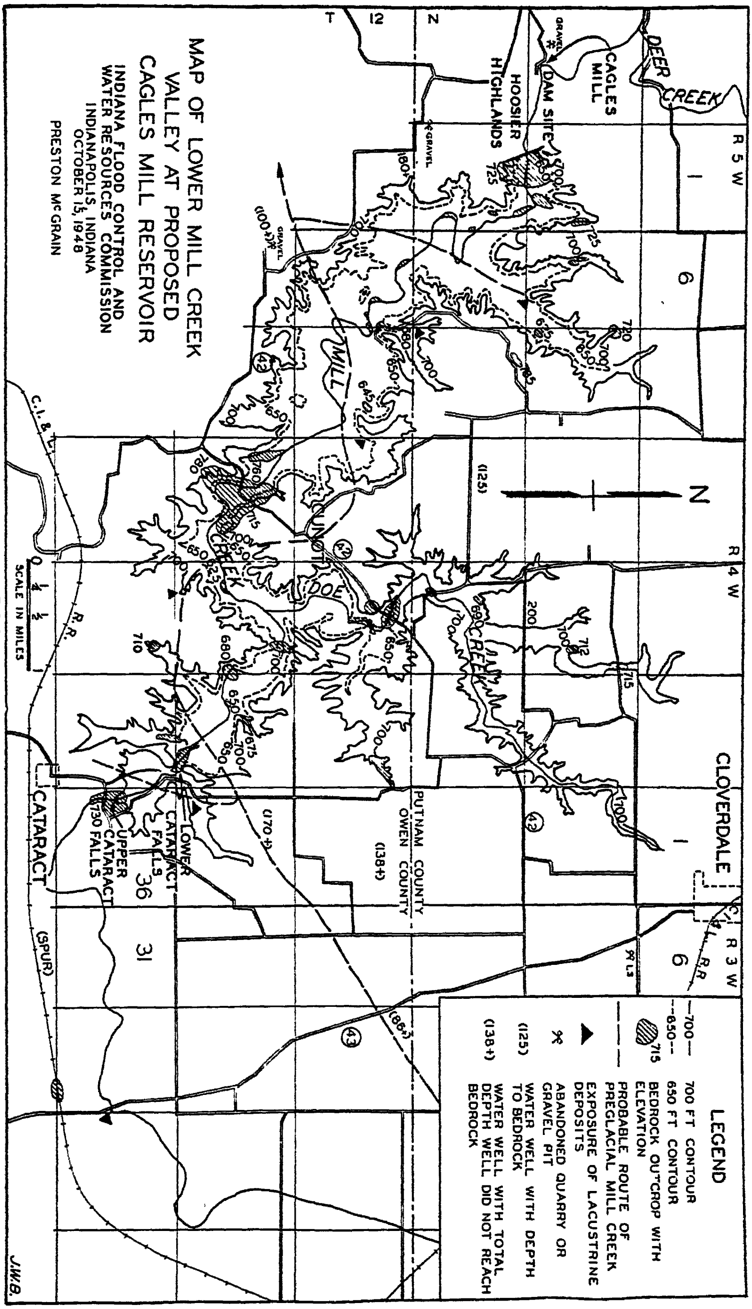
Glacial Drift

Waterlaid glacial sand and gravel—20 feet exposed.

Lacustrine Deposits

Gray and tan laminated, calcareous silt; basal part mostly fine sand in which lamination is indistinct—20 feet.

Gray, laminated, calcareous, sandy clay—4.5 feet exposed to creek bed.


MAP OF LOWER MILL CREEK
VALLEY AT PROPOSED
CAGLES MILL RESERVOIR
INDIANA FLOOD CONTROL AND
WATER RESOURCES COMMISSION
INDIANAPOLIS, INDIANA
OCTOBER 15, 1948
PRESTON McGRAIN
LEGEND
—700— 700 FT CONTOUR
--650-- 650 FT CONTOUR
715 BEDROCK OUTCROP WITH ELEVATION
PROBABLE ROUTE OF PREGLACIAL MILL CREEK
EXPOSURE OF LACUSTRINE DEPOSITS
ABANDONED QUARRY OR GRAVEL PIT
(125) WATER WELL WITH DEPTH TO BEDROCK
(138+) WATER WELL WITH TOTAL DEPTH WELL DID NOT REACH BEDROCK
DEER CREEK
CAGLES MILL
DAM SITE
HOOSIER HIGHLANDS
GRAVEL
MILL
CUNOT
DOE CREEK
CREEK
CLOVERDALE
CATARACT
LOWER CATARACT FALLS
UPPER CATARACT FALLS
PUTNAM COUNTY
OWEN COUNTY
T 12 N
R 5 W
R 4 W
R 3 W
C.I. & L. R.R.
(SPUR)
SCALE IN MILES
0 ¼ ½ 1
N
J.W.B.

Other silts were observed in the northeast quarter of Section 18, T. 12 N., R. 4 W., on the end of the spur formed by a south flowing tributary of Mill Creek on the west and a southwest flowing tributary on the east. Beyond this point Mill Creek enters a narrow, bedrock, gorge-like valley and evidence of lacustrine deposits disappear.

A possible route of the former channel of Mill Creek has been indicated in figure 3. This interpretation is based upon field data derived from a study of the physiography of the lower Mill Creek valley and the examination of a number of water well records. The presence of lacustrine deposits, absence of bedrock, and unusual depths to bedrock in water wells were the controlling factors in making this interpretation. It is believed that ancient Mill Creek roughly parallels and lies to the north of the present stream until reaching the vicinity of Lower Cataract Falls. Mill Creek crosses the buried valley just below this falls and apparently again three-fourths of a mile southeast of the village of Cunot in northwestern Owen County. A noticable lack of detailed control occurred at Cunot. In this community domestic water supplies are derived from cisterns and shallow dug wells and, consequently, little bedrock data were available. Three-fourths of a mile west and a little north of Cunot, Mill Creek again intercepted the buried valley and generally followed it until it crossed a bedrock ridge at Mill Creek Valley Camp near the center of the west side of Section 20, T. 12 N., R. 4 W. From this point the buried valley appears to have turned west and northwest. Lack of well data and outcrops have prevented further detailed mapping of its route at this time.

The presence or absence of the bedrock ridges has a very striking effect upon the size and shape of the lower portion of present Mill Creek valley. Where the stream encounters bedrock, even though relatively low in elevation, the valley is narrow and in places even gorge-like. At the proposed dam site only a suggestion of a valley flat exists. (figure 4). At this point Mill Creek exhibits the characteristics of a stream at

Fig. 4. View looking southwest along the center line of the proposed dam site. Photo by W. T. Powers.

early maturity. Similar conditions exist at Mill Creek Valley Camp, at Croy's Mill southwest of Cunot, at a ridge in the northeast quarter of Section 27, T. 12 N., R. 4 W., and at Lower Cataract Falls. Where the present Mill Creek intercepts its buried ancestorial valley or one of the buried tributaries, the profile assumes the shape of a broad, nearly flat-bottomed "U." The greatest development of this latter valley shape may be seen in Sections 19 and 20, T. 12 N., R. 4 W., immediately upstream from Mill Creek Valley Camp where the valley flat is fully three-fourths of a mile to a mile wide (figure 5). Other striking examples of these broad valley flats adjacent to the narrow bedrock valley were observed about a mile downstream from Mill Creek Valley Camp, immediately below Lower Cataract Falls and immediately below Upper Cataract Falls. From an engineering point of view the V-shaped, rock-walled valleys are most desirable for dam sites and the broad, flat valleys with high walls provide for the storage areas for impounding waters during periods of excess runoff. However, if there are prolonged periods during which the flood pool is high, objectionable leakage might occur through the coarser lacustrine sediments at points where the divides between Mill Creek and the King Creek watershed to the southwest are narrow, such as occurs in the southwest quarter of Section 19, T. 12 N., R. 4 W. As indicated in a previous paragraph, where exposed, the lacustrine deposits consist of thinly laminated calcareous clays, silts, and very fine sand which appear to be of very low porosity and permeability. Local water well drillers reported that this material is unsatisfactory as an aquifer for domestic water supply. Also, the lower portions of the lacustrine deposits were clays, while the sands seemed to be more common in the upper part of the deposit.

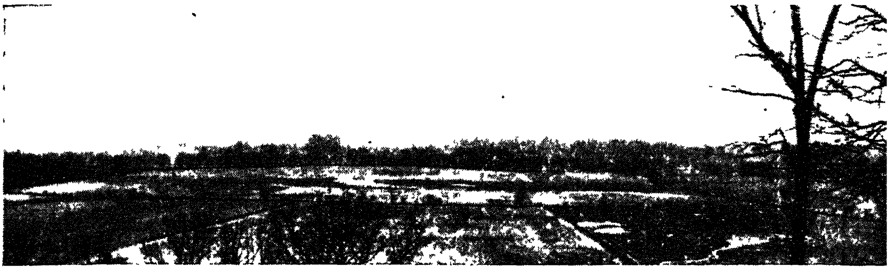


Fig. 5. View of Mill Creek Valley where the present stream has intercepted its buried ancestorial route. Photo by W. T. Powers.

The bedrock stratigraphy of the Mill Creek valley area is relatively simple, however, exposures are not common. Malott ((4), p. 324) gives the following composite section at Upper and Lower Cataract Falls:

Chester

Paoli limestone and shale—17 ft., 6 in. exposed.
Aux Vases calcareous sandstone—3 ft., 9 in.

Ste. Genevieve
    Levias limestone—22 ft.
    Rosiclare calcareous sandstone—23 ft.
    Fredonia limestone—30 ft., 6 in.
    St. Louis limestone—9 ft. 6 in. exposed.

The following is a composite stratigraphic section measured by the writer in gulleys on the south side of Mill Creek near the proposed dam site.

PENNSYLVANIAN

Mansfield
    Fine to medium-grained, massive sandstone; concentration of iron at base—50 ft. exposed.
    Gray shale with many clay iron-stone concretions—0.22 ft.

MISSISSIPPIAN

Chester
  Beaver Bend
    Hard, gray, fine-grained limestone—5 ft.
  Mooretown
    Mostly covered with shows of gray and tan shale—17 ft.
  Paoli
    Single bed of dense, gray to tan limestone with small pyrite crystals; upper 6 inches rather coarsely crystalline limestone—3.5 ft.
  Aux Vases
    Soft, gray shale—1 ft.
    Covered slope—3 ft.
Meramecian
Ste. Genevieve
  Levias member
    Cross-laminated, light to dark gray, oölitic limestone; rests unevenly upon lower limestone strata—10 ft.
    Thin, even-bedded, hard, gray, semilithographic limestone—7 5 ft.
    Tough, gray, rubbly limestone breccia; traces of glauconite—4.5 ft.
  Rosiclare member
    Generally even-bedded, fine-grained, light gray, calcareous sandstone—2.3 ft.
    Cross-laminated, fine to medium-grained, light gray, calcareous sandstone; friable on weathered surface—3.3 ft.
  Fredonia member
    Covered slope—4.5 ft.
    Porous, mottled, tan dolomite—1 ft.
    Covered slope to Mill Creek—5 ft.

Excellent exposures of the upper part of the Ste. Genevieve formation and lowest Chester beds were observed in the very recent excavations for the diversion tunnel of the reservoir on the north side of Mill Creek at the proposed dam site. The interval correlated in the above composite section with the Aux Vases was represented at the intake end of the diversion tunnel by 4 feet of calcareous, blue-gray and green shale with oölitic limestone pebbles and sandstone pebbles and lenses. These Aux Vases beds are underlain by 2 to 3 feet of irregularly brecciated limestone with occasional quartz grains which this writer has recognized as a persistent lithologic facies of the Ste. Genevieve formation thoughout its outcrop area in southern Indiana. A cursory examination of other exposures at the site of the diversion tunnel revealed that other members of the Ste. Genevieve do not occupy their normal intervals at this locality and display a wide variation within short distances. However, these variations should have no influence upon the effectiveness of the proposed dam and reservoir.

According to borings made by the U. S. Army Engineers there is as much as 35 feet of valley fill material in the dam site area.

Prominent exposures of limestone are present in all the gorges listed in a previous paragraph, but the detailed stratigraphy is not always apparent. Unless the Rosiclare or Aux Vases sandy beds are developed and exposed, differentiation of the beds is difficult, as few fossils are present. The Rosiclare has been recognized at Croy's Mill but it is not exposed in either the bedrock ridge at Mill Creek Valley Camp or Cagle's Mill. At Mill Creek Valley Camp the top of the Ste. Genevieve may be identified by the presence of a rubbly, limestone breccia. At Cagle's Mill, one mile downstream from the proposed dam site, the Aux Vases is represented by 1 foot of fine-grained sandstone near the top of the limestone beds. The Rosiclare here is below drainage level.

Although limestone constitutes the biggest part of the bedrock section along Mill Creek, karst features are generally absent. An exception to this is a sink-hole area along Indiana Highway 42 near Doe Creek bridge high above Mill Creek at elevations near 730 feet. The absence of solution features in this normally karsted limestone formation can probably be explained at least in part by the protective cover of lacustrine silts since Illinoian times and the presence of the impervious bed of Pennsylvanian shale which overlies the limestone strata in the western part of the area. This latter feature is particularly well developed in the vicinity of the proposed dam site and has probably aided to a great extent in preventing the limestones from being made cavernous in this locality. Also, since the limestone strata at the dam site were exposed after Illinoian glaciation there has not been sufficient time for the formation of solutional features.

Although the writer has not tried to emphasize the applications of geology to sound engineering practices the facts pointed out in the above discussion cannot be minimized. First, if the present Mill Creek had encountered bedrock throughout its full distance, and not the soft, unconsolidated Pleistocene sediments, the valley would have been narrow, and would not impound sufficient water to justify a flood control reservoir site. Conversely, if this stream had not encountered bedrock the cost of a dam would have been multiplied many times and numerous difficult engineering problems would have been encountered. Thirdly, a protective blanket of Pleistocene and Pennsylvanian sediments has obstructed the downward percolation of meteoric waters into the well jointed and bedded, soluble Ste. Genevieve limestone. Thus, an unusual combination of physiographic and geologic features have produced an area which is probably unrivaled in Indiana for a flood storage reservoir.

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Ground Water Resources of Henry County, Indiana

PRESTON MCGRAIN

Indiana Flood Control and Water Resources Commission*

Introduction

Purpose and Scope. A study of water problems in headwater areas in Indiana led to the study of ground water resources of Henry County. This county derives almost all its water from precipitation which falls within its borders, and ground water is used almost to the exclusion of surface water supplies for municipal, industrial, domestic, and livestock purposes. It is the purpose of this paper to present the results of the survey of these ground water resources.

The present report is preliminary in scope. Field investigations of the ground water resources and geological features of the county were made in the fall of 1947. Heretofore little attention has been given to the geology of Henry County. Since there is a direct relationship between the character of rock formations and the presence of ground water a study of the thickness and important lithologic characteristics of each formation was imperative. The geology of the county as well as an account of the sub-surface water supplies is discussed herein.

Location. Henry County is located in east-central Indiana, approximately half way between Indianapolis and the Indiana-Ohio state boundary. Its length from north to south is 20.0 miles and its width is 19.5 miles. It covers an area of 389.4 square miles according to planimetric calculations. Henry County is bounded on the north by Delaware County, on the east by Randolph and Wayne counties, on the south by Fayette and Rush counties, and on the west by Hancock and Madison counties. New Castle, the county seat, is located approximately in the geographic center of the county, at the longitude of 85 degrees 20 minutes west and latitude of 39 degrees 56 minutes north.

U. S. Highways 35, 36, and 40, and Indiana Highways 3, 38, 103, 109, 234, and 236, all hard surfaced roads cross the county. There are numerous other roads of various degrees of improvement.

The Pennsylvania, New York Central, Nickel Plate, and Chesapeake and Ohio railroads also serve Henry County.

Acknowledgements. In addition to the information collected in the field, numerous persons and publications were consulted for data incorporated in this report. Publications referred to are listed in the bibliography. Many well records and much general information was secured from active and retired well drillers in the area. Well owners throughout the county and several county officials contributed much information regarding water conditions in specific areas. This report would not have been possible without the cooperation of all these people.

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* Published by permission of the Chief Engineer, Indiana Flood Control & Water Resources Commission.

Physiography

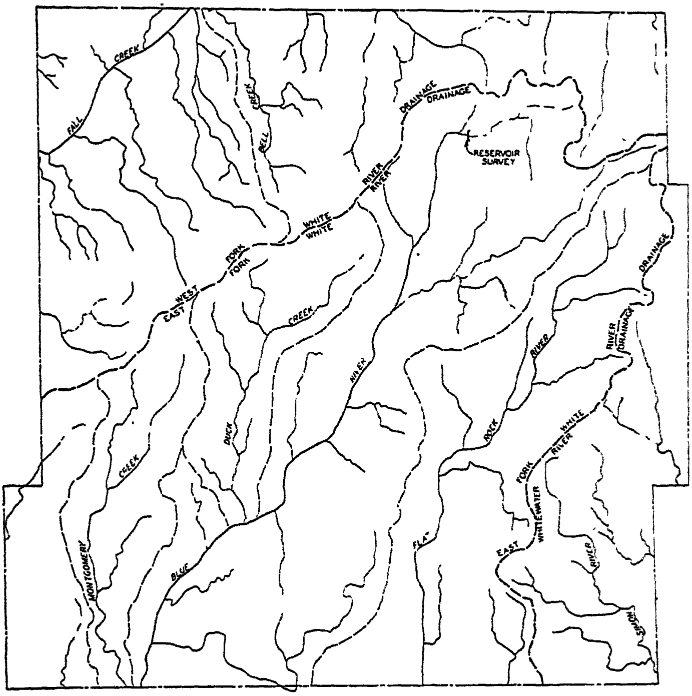
Topography. Physiographically, Henry County lies entirely in the Tipton Till Plain. The Tipton Till Plain, which merges imperceptibly on the south with the Muscatatuck Regional Slope, is characteristically a slightly modified glacial ground moraine plain and over wide areas is monotonously flat. The chief inherent irregularities of the plain are the terminal moraines and their associated features. These are features of glacial construction superimposed on the till plain. Only where the till plain is marked by terminal moraines and where it is cut by troughlike valleys of the main streams does it exhibit a diversified topography. Bedrock exposures are limited to a single small area on Blue River. Elsewhere there lies beneath the glacial drift a diversified erosion surface hidden from view by a considerable cover of glacial drift. It is not unlikely that in preglacial times the relief of this area was comparable to that of parts of southern Indiana at the present time. Well records indicate a maximum bedrock relief of over 500 feet.

Much of Henry County is characterized by glacial morainic belts. In northern Henry County, in the vicinity of Mt. Summit, a system of ridges and knolls rises rather abruptly 75 to 100 feet above the bordering glacial sluiceway near the headwaters of Blue River. This morainic mass is thickly strewn with boulders and is characterized by sloughs and shallow basins between the sharp ridges and knolls. The morainic tracts in southern Henry County are somewhat subdued and are nowhere as prominent as the northeastern area.

A moraine traverses the county from southwest to northeast, passing west and north of New Castle, which constitutes the divide between the East and West forks of White River. On the eastern border of the county there is a moraine with a gently undulating surface which forms the divide between the East Fork of White River and the Whitewater River systems.

The maximum elevation in Indiana centers around an area in the east-central part of the state, which includes part of Henry County. It is reported that the average altitude of Henry County is 1040 feet above mean sea level; this is second only to adjacent Randolph County on the east. The maximum altitude of Henry County is reported to be 1150 feet, the minimum altitude to be 880 feet, and the maximum local relief to be 100 feet (Malott (10), p. 81).

Drainage. Henry County is a headwaters county which lies almost entirely within the drainage basin of the Wabash River. By far the greatest part of the water of Henry County is derived from precipitation within the borders of the county. It is estimated that less than 5 percent of the water fed into Henry County streams is derived from sources outside of the county.



DRAINAGE MAP OF HENRY COUNTY

SHOWING STREAMS WATERSHEDS AND SITE OF RESERVOIR SURVEY

INDIANA FLOOD CONTROL AND WATER RESOURCES COMMISSION
INDIANAPOLIS, INDIANA OCTOBER 15, 1948

SCALE OF MILES

FIG. 1

Henry County can be divided conveniently into three main drainage areas (figure 1). The largest of these drainage areas is that of the East Fork of White River which covers about 237.3 square miles or a little more than 60 percent of Henry County. The north and northwest tributaries of West Fork of White River drain approximately 101.7 square miles. The remainder of the county, some 40.4 square miles, is drained by tributaries of the Whitewater system which in turn empties into the Miami River northwest of Cincinnati, Ohio.

The Tipton Till Plain, as a constructional feature in the zone of ice wastage, was a plain without valleys, but as the ice melted from the region the older and first exposed portion of it was subject to overflow by the waters coming from the ice of the portion still under construction. Consequently, there are broad valleys leading southward and southwestward across the plain. Most of these glacial waterways are now occupied at least partially by streams, though in all cases very small and feeble compared with their Pleistocene ancestors which, during the melting periods, occupied the whole of the valley and excavated it practically as it is today. Blue River, Flat Rock River, and Fall Creek valleys are valleys which owe their existence largely to the work done by glacial waters. The streams which now occupy these valleys have modified them very little since the close of the glacial period and are but feeble representatives of their mighty progenitors.

The headwaters of Blue River flow into a wide glacial sluiceway on the east side of Section 12, T. 18 N., R. 10 E., about 3 miles northeast of Mt. Summit, and then flow in a south and southwesterly direction in a valley which is approximately one-half mile wide. Buck Creek and part of its tributaries occupy the upper part of this sluiceway and instead of flowing south into Blue River they flow northwest and north to join the West Fork of White River at Yorktown, Delaware County. Similarly, part of Bell Creek (a north flowing tributary of Buck Creek) and the headwaters of Fall Creek occupy a continuous southwesterly trough in western Henry and Delaware counties.

Stratigraphy

The bedrock stratigraphy of Henry County has long been a challenging and puzzling problem. Little can be learned from the poor exposures at the surface, and most well records contain insufficient data from which to accurately determine the bedrock sequence. The following generalized stratigraphic succession is an attempted interpretation of formations encountered based on field observations, information obtained from drillers, and older geological reports.

- Quaternary
  - Recent alluvium—0-30 ft.
  - Pleistocene glacial drift—0-535 ft.
- Silurian—0-200 ft.
- Ordovician
  - Cincinnatian Series—650-785 ft.
  - Trenton limestone—150 ft.
  - *Back River group—320 ft.
  - *Glenwood-St. Peter formations—35 ft.
- *Cambro-Ordovician Series—1330 ft.
  - *Prairie du Chien (Lower Ordovician)
  - *Trempealean (Upper Cambrian)
- *Cambrian
  - *Eau Clair sandstone—610 ft.
  - *Mt. Simon sandstone—320 ft.
- *Pre-Cambrian—30 ft. plus

*After Bieberman and Esarey (1)

Quaternary. The Quaternary includes all the unconsolidated sediments overlying the bedrock surface. These sediments consist of valley inwash deposits which occupy parts of buried bedrock valleys, all types of glacial drift, and fluvio-glacial deposits, all Pleistocene age, and of Recent alluvial materials.

The Recent alluvial deposits in Henry County are confined to flood plains and alluvial fans. They are chiefly sand and silts. No towns and relatively few homes are located in the broad valleys of Henry County streams consequently there is little dependence on the alluvial deposits for water supply.

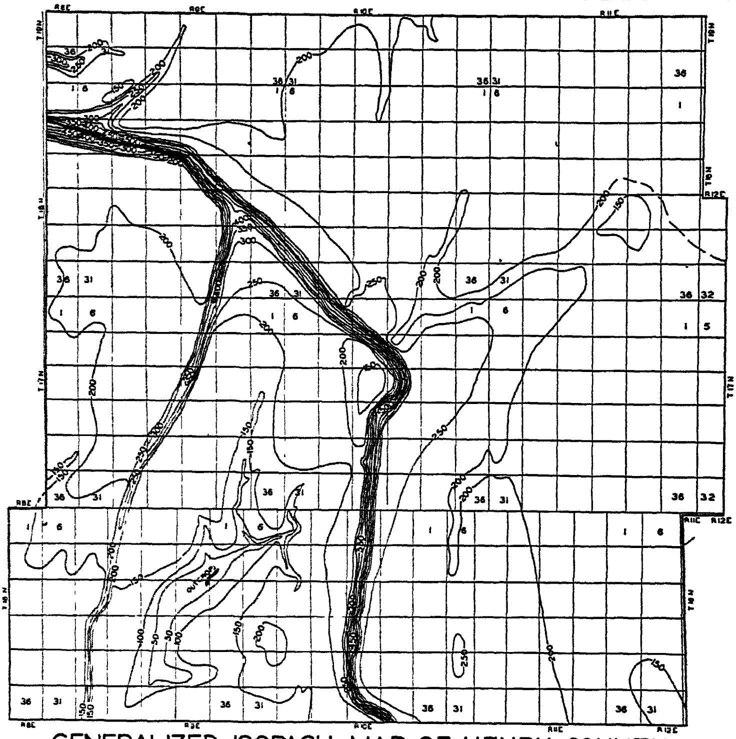
Two periods of glaciation have been recognized in Indiana. In Henry County the Wisconsin drift completely hides the older Illinoian drift which may be interpreted only from well logs and samples. The glacial material may be divided into three general types. The first type is terminal moraine material which is ridge-like accumulations of debris made at the end or edge of an ice sheet, especially where its end or edge has remained stationary for a considerable time. The moraines consist of a heterogeneous mixture of glacial debris varying in size and composition from minute clay particles to massive limestone and granite boulders. With the unsorted drift and till are lenses or pockets of more or less stratified sands and gravels which are interbedded in an uncertain and unsystematic manner. Basins and other depressions between the ridges have often been filled with silt and frequently are marshy or swampy areas.

The second type of glacial deposit recognized in Henry County is ground moraine material. The ground moraine consists of all the drift deposited beneath the advancing glacier and drift deposited from the base of the ice during its recession through melting. The ground moraine is made up of a compact, impervious, clayey material containing scattered sand, gravel, pebbles, and boulders. The till of the ground moraine areas contains more clay and is generally more compact and impervious than the till of the terminal moraine areas, which is more sandy and which sometimes includes isolated permeable masses of gravel. It, like the terminal areas, may be deduced largely from the surface topography.

The third type of glacial material recognized is that deposited by meltwater from the ice. The fluvio-glacial materials in Henry County consist of outwash plains and some valley train-like material which is found principally in the valley of Blue River. The outwash plans are large, relatively flat topographic features constructed of all detrital material swept out of the melting glacier by meltwater streams. The material consists largely of more or less imperfectly sorted and stratified sand, gravel, and silt.

In view of the fact that the Wisconsin is the younger of the two glacial deposits it is the one which is represented by the above glacial materials. The presence of the Illinoian drift is recognized in subsurface investigations by the presence of an old soil or a leached or oxidized zone well below the surface of the ground. (Thornbury (11), p. 45) has indicated that the average depth of leaching of Wisconsin drift in Henry County is 30.3 inches.)

The thickness of the blanket of glacial drift varies from zero (at one locality in the bed of Blue River) to a reported depth of over 500 feet near New Castle (Leverett (7), p. 30) and (Harrell (4), p. 256). Buried bedrock valleys and other irregularities of the bedrock surface account for the unusual thickness. In some of the literature bearing on the problem it has been suggested that the material occupying the "deep drives" in Henry County is composed of glacial drift similar to the materials at the surface, but it is here suggested that these former northward flowing tributaries to the great Teays valley were blocked by the southward advance of the Pleistocene ice sheet and at least partially filled with stillwater accumulations, such as muds and silts, thus forming poor water-bearing material. (The Teays Valley is a high level valley which rose in Tertiary time in the Blue Ridge Mountains in North Carolina, and flowed west and northwest across West Virginia, Ohio, Indiana, and Illinois. It is believed to have dis-



GENERALIZED ISOPACH MAP OF HENRY COUNTY

SHOWING AVERAGE THICKNESS OF GLACIAL DRIFT

ISOPACH INTERVAL 50 FT.

INDIANA FLOOD CONTROL AND WATER RESOURCES COMMISSION

INDIANAPOLIS, INDIANA OCTOBER 15,1948

PRESTON McGRAIN

J.W.B.

FIG 2

charged into the Gulf Embayment through bedrock valleys now generally occupied by the present Illinois and Mississippi rivers. That portion of the valley in western Ohio, Indiana, and Illinois is buried beneath glacial drift and its route across this area has been traced by means of well records.)

The presence of deeply buried bedrock valleys in Henry County has been suggested in several of the older geological reports on the region and is considered common knowledge among water well drillers in that area. To this writer's knowledge no previous attempt has been made to trace these features or describe their extent in Henry County. Records of over 450 wells were gathered and studied.

An isopach map with intervals of 50 feet showing the average thickness of glacial drift in Henry has been prepared (figure 2). The thickness of the glacial drift is the combined result of the topography of the buried bedrock surface, the amount of glacial deposition, and the depth of subsequent stream dissection. For the purpose of this map all unconsolidated sediments are interpreted as glacial material. The degree of accuracy will vary in different areas with the availability of well data and the local topography. Generally, it is unnecessary to drill much over 100 feet for water in Henry County. No topographic maps of Henry County are available; also, time did not permit a topographic survey in conjunction with this phase of the study. Consequently, the thickness of the glacial drift must of necessity be generalized and considered average for any particular locality. Further, the isopach map is based only on well records in which the location could be determined with some degree of accuracy.

Silurian. Very little is actually known about the bedrock which underlies Henry County's 389 square miles. Bedrock formations come to the surface in the bed of Blue River just south of the bridge at Stone Quarry Mill, 1¾ miles west of Spiceland. The quarries, reported by Kindle ((6), p. 427), have long since been inactive and their location can be determined only by the presence of deep pools or ponds of water north of the bridge and west of the present saw mills. Cumings and Shrock ((2), p. 172) describe rock from one of the quarries, present in the foundation of one of the mills, to be Silurian in age. The present writer believes that this rock and other rock fragments scattered in the vicinity of the abandoned quarries to be partially altered by burning for lime.

Local residents report that stone was exposed for a few hundred yards in the bed of Blue River a short distance below the bridge when this stream was dredged some 15 or 16 years ago. Now, however, alluvial sand and gravel covers most of this area and rock is seen only when the water is low and clear. This stone is a slabby, grayish to tan or light brown, granular, somewhat porous dolomitic limestone. Occasional imperfectly preserved casts of brachiopods represented the only faunal evidence observed. Lithologically this stone resembles some of the beds of Huntington dolomite which outcrops much farther north.

Another opportunity to view the type of stone which might be present beneath the glacial drift in this area is at a stone culvert under the road opposite the northeast corner of the Spiceland School lot. It was reported to the writer that the slabby, cherty, gray limestone used in the construction of this culvert originally came from one of the now abandoned quarries at Stone Quarry Mill to the west. The abundance of chert in these tabular pieces of stone suggest the Liston Creek formation; however, neither the stratigraphic position nor the faunal characteristics could be determined from surface examination of the area.

A few cuttings from a water well at the southwest end of Indiana Highway 3 overpass just west of Dunreith were observed by the writer. These cuttings, which came from the top of the bedrock at a depth of 152 feet, consisted of hard, very fine grained, grayish white, somewhat dolomitic limestone.

Ordovician and Cambrian. No outcrops of Ordovician or older rocks are known to be present in Henry County. In the past many wells have been drilled to the Trenton for gas or oil and, at the present, a few wells in the vicinity of Knightstown are producing small quanities of natural gas.

Bieberman and Esarey ((1), Pl. 1) describe a deep test drilled by the Ohio Oil Company in the SE ¼ of the NE ¼ of Section 12, T. 16 N, R. 11 E., near New Lisbon which was drilled into granite. The total depth was 3670 feet. Limestone belonging to the Cincinnatian Series (Upper Ordovician) was first encountered beneath the 180 feet of glacial drift which blankets that particular area. This extends the previously known areal extent of the Ordovician. Besides the formations of the Cincinnatian Series, the Trenton and Black River limestones, and Glenwood, St. Peter, and Prairie du Chien formations, all Ordovician, and the Trempealean formation and Eau Claire sandstone, Cambrian, were tentatively identified and correlated by Bieberman and Esarey ((1), Pl. 1).

Samples from oil test on the S. L. Roof farm, in the SW¼ of the SW ¼ of Section 18, T. 17 N., R. 10 E., some 4 miles west of New Castle, drilled in 1948, were studied by the writer. In this case the rock was first encountered at 229 feet. No samples of the glacial material were saved. A description of some of the rock encountered follows.

SILURIAN

229-237—White to tan, crystalline, dolomitic limestone.

237-242—Red clayey material; decomposed limestone

242-252—Light gray, finely crystalline dolomite with chert and glauconite.

ORDOVICIAN

252-257—Soft blue-gray, calcareous shale, "Little Break" of well drillers.

257-272—Gray, very fine grained, dolomitic limestone

272-325—Soft blue-gray, calcareous shale; "Big Break" of well drillers.

325-363—Gray to white, fine to carsely crystalline, dolomitic limestone and dolomite.

Pre-Cambrian. The above mentioned Ohio Oil Company test near New Lisbon was drilled 30 feet into Pre-Cambrian before being abandoned. The Pre-Cambrian at this point consisted of red granite.

Structure

The regional structure of Henry County is directly controlled by the presence of the northwestern prong of the Cincinnati Arch, which enters Indiana from the southeast. This anticlinal structure, which enters the county from the southeast, is broad and rather flat-topped. Logan ((9), P. 347) reported that the upper surface of the Trenton limestone in the central and southeastern portions of the county is 100 feet above sea level, and is 50 feet above sea level in the northwestern part of the county.

Ground Water

Source and Storage. If the water-bearing materials of Henry County were uniformly porous, permeable, and homogenous, ground water problems could probably be solved by hydraulic data, and the studies of the geologic nature of the water-bearing materials would have been unnecessary. However, as pointed out previously, the materials below the ground in Henry County are heterogenous and their geologic characteristics are varied. It is these variations that control the distribution, quantity, and quality of the ground water. The satisfactory solution of many ground water problems usually involves the putting down of either prospect or test holes, or both, sooner or later.

The formations which underlie the surface of Henry County are saturated with water below a level known as the water table, which ranges greatly in depth. By definition the water table is the upper surface of the zone of saturation in ordinary permeable soil or rock. It is necessary for wells to penetrate the water table if they are to be productive, and even then other factors may prevent the well from being a source of water. The water table is deepest in some of the highest parts of the upland areas and is shallowest in the lowlands. In marshes the water table lies continuously or intermittently above the surface of the ground. The water table does not occupy a fixed position at any given place but fluctuates with rainfall and drouth, being highest just after a period of prolonged precipitation and lowest at the end of a long drouth. The water table has irregularities comparable with and related to those of the land surface, although it is less accentuated. The ground water horizon, if underlain by an impervious layer may be separated from the main body of ground water by an unsaturated or partially saturated rock. The upper limit of a relatively high isolated and local body of saturated material may be referred to as a perched water table.

By far the greatest part of the ground water of Henry County is derived from precipitation within the borders of the county. Practically the whole county is covered from several feet to several hundred feet by glacial drift. Therefore, rainwater which falls on the surface has a chance to penetrate the glacial covering, provided the precipitation is slow and other factors are favorable. In this manner it is believed that precipitation reaches the sand and gravel horizons, the bedrock surface, and the deeper formations. When formations appear at the surface the precipitation has an opportunity to penetrate the strata directly, provided they are porous, and such water may go down the dip of the formations. Similarly, water may move along bedding planes, joints, and other fractures of the rock formations.

Aquifers. An aquifer is a geological formation that transmits water in sufficient quantity to supply pumping wells or springs. An aquifer may be local or widespread. The most important source of water supply in Henry County is from local aquifers in glacial drift. The occurrence of the aquifers in the glacial drift is subject to much variation both locally and regionally. During the course of this survey many reports of the variations in depths of wells came to the attention of the writer. A good example of such a variation is the situation at a group of houses near the junction of Indiana Highways 38 and 234, four miles west of New Castle, where a well, drilled in 1947, is producing water at a depth of 26 feet in glacial drift while neighboring wells had to go 182 to 191 feet to limestone for sufficient water to supply needs for home use.

Water supply in glacial drift will vary depending whether or not the material is glacial till, moraine, or glacio-fluviatile deposits. Wells drilled into till are seldom water-bearing, as till masses are so close textured or so compact that they will not furnish water fast enough to supply the wells. Usually satisfactory supplies must encounter sand or gravel deposits in the glacial drift. In many cases a looser textured bed is found with deeper drilling though in some localities such beds do not exist. If satisfactory supplies are not found in the glacial drift, the well must penetrate the bedrock if the formations are known to be water-bearing.

Lenses and pockets of sand and gravel are the chief water horizons of terminal moraines. Their occurrences in the moraines are uncertain and unsystematic. Therefore, any well drilled in a moraine area must take this fact into account. As in the case of till areas the quantity of water secured from these sand or gravel lenses depends upon their vertical and horizontal extent. The contact between the piled-up terminal moraines and the underlying ground moraine is often an excellent water horizon, especially where deposition of sands and gravels has occurred on top of the ground moraine. Those portions of terminal moraines which consist primarily of boulder clay are low in permeability and yield little water.

Outwash plains composed of water sorted sands and gravels are closely related to the moraines next to which they occur. Such plains are not found adjacent to every moraine or all parts of any moraine. Outwash plains receive much of their water directly from precipitation and from the adjacent moraines by seepage and regular flow of ground water into them. Ground water is found in the coarser deposits of the outwash material usually some depth below the surface.

The contact between the glacial drift and bedrock is frequently an excellent horizon for local water supplies. For some distance along Blue River valley between Greensboro and Knightstown a six-inch bed of coarse, water-bearing gravel occurs at the top of the underlying limestone. It is not to be construed that ground water will be found in all wells at the contact between the drift and the bedrock, for in many cases clay or very fine sand rests on the rock.

In view of the fact that the glacial drift is very thin in the southwestern part of Henry County, especially just northeast of Knightstown, and that the glacial drift interval anywhere in the county may be occupied by clay till and/or very fine sand, it is not an uncommon occurrence to have to search for ground water supplies in the bedrock. The upper portion of the bedrock, particularly that which is in contact with the glacial drift, is often porous and serves as an aquifer satisfactory for domestic water supply. This water is generally potable but salt water was reported to have been encountered in one well in Silurian limestone at the State Epileptic Village north of New Castle. In Wayne and Spiceland townships bedrock wells are common. Municipal supplies for the towns of Knightstown and Spiceland are secured from wells in limestone. Water also occurs frequently in the joints, crevices, and bedding planes of the Silurian limestone.

In the southeastern corner of Henry County and along the bottoms of the deeply buried bedrock channels the shales and shaly limestones of the Cincinnatian Series (Upper Ordovician) occur beneath the glacial drift. Little or no water is present in these strata.

Records of wells into the Trenton formation (Middle Ordovician) indicate that water in that formation is usually salty. An earlier writer, however, reported that some fresh water was found in the Trenton at Knightstown. Artesian flow of fresh water was observed by the writer to be coming from abandoned gas wells near Maple Valley in southwestern Henry County, but the water horizon could not be determined. The town water supply for Shirley on the Henry-Hancock county line is from an abandoned gas test but again the aquifer could not be ascertained since the casing in old wells will deteriorate after a period of years and the water might come from any of several potential water horizons. There is no information on water horizons deeper than the Trenton.

Methods of Recovery. Ground water in Henry County is recovered from springs, dug wells, driven wells, and drilled wells, the latter method of recovery being the most widely used at the present time.

Springs and seeps are usually quite common in morainal areas and Henry County is no exception. Springs are particularly plentiful along the more deeply entrenched streams where the valley has intercepted beds of water-bearing sand or gravel. Such sources of water occur along the valley sides of Blue River, Montgomery Creek, Fall Creek, and Buck Creek. The community of Springport was settled because of the presence of excellent water supply from this source. At the present time an estimated 100 or more small artesian wells and springs provide the local water needs.

The earliest wells in the county were dug by hand usually to a depth of 10 to 30 feet. Generally they were considered adequate at that time but many of these shallow wells did not produce large quantities of water. Water was usually raised by small hand pumps or by buckets.

Driven wells 1¼ to 2 inches in diameter have also been used to secure ground water. This method was often used because an individual could drive a shallow well with little or no assistance. However, the very nature of this method made it impossible to learn much about the nature of the rock materials encountered. Most of the houses in the community of Honey Creek obtain water from 1¼ inch driven wells at a depth of 18 to 26 feet. These wells are reported capable of producing approximately 120 gallons each per hour.

The most widely used method of securing subsurface water in Henry County at the present time is by drilling. Most wells are 4 inches in diameter; however, larger wells, 6, 8, and 10 inches in diameter, are drilled for industrial and municipal uses. Only on the rarest occasion is anything smaller than a 4 inch well currently drilled.

A great many factors over and above the varied geological conditions affect the depth of the well and the amount of water which it will produce. The depth of these 4 inch water wells ranges from less than 30 feet to more than 200 feet. The initial capacities of the wells range from 200 to 900 gallons per hour, generally about 500 to 600 gallons per hour. These tests are considered a minimum rather than maximum capacity. What is considered a satisfactory water supply often is dependent upon the interpretation of the driller on the job and the owner of the well. The determination of a suitable aquifer and satisfactory pumpage varies with the individual. One driller will pass up a water bearing horizon when the sand or gravel will not stand up in the hole, while another driller will use a screen for the same condition. (It should be noted that the use of screens in wells also varies with the individual driller. Some drillers will equip every well with a screen while other drillers will not make a well in a water-bearing horizon if a screen is necessary; the latter contends that a screen may often clog up and the well will require periodic servicing.) In the case of a well in glacial drift, gravel the size of wheat grains is considered minimum requirements for a well. Even though a bed or lens of sand might carry a copious supply of water, sand has a tendency to be carried upward and thus clog the hole. Still other aquifers contain so much fine silt and clay that the water never becomes clean and, consequently, is not satisfactory for domestic use. Wells for water supply for livestock use does not have to meet as strict requirements as those for homes, businesses, etc.

Wells into the limestone of Henry County do not encounter the varied conditions found in glacial sand and gravel; consequently, the personal factor is not as pronounced. Drilling in the limestone is continued until a sufficient quantity of water is reached or until the potential water-bearing formation has been penetrated. Limestone wells are drilled, not dug or driven, and the water is usually encountered in the upper parts of the formation.

No limestone springs occur in Henry County because of the restricted outcrop area. However, artesian flow from wells drilled in limestones is encountered occasionally because the aquifer is fed from a higher elevation.

Local Ground Water Problems. Considerable interest and concern in the subsurface water supply has been shown by the citizens of Henry County in recent years. The writer believes that the concern over the conditions is due primarily to the greatly increased domestic and farm use and the increased suburban and urban population. The advent of the rural electrification program brought in larger, electrical driven pumps and subsequently running water throughout the suburban and farm homes. It is estimated that the household and farm consumption in such cases has been increased at least 3 or 4 times and in some cases up to 20 times. Consequently, the relatively shallow, hand-dug, and driven wells do not meet these increased demands. Also, the capacity of the new pumps exceeds the flow from the shallow aquifer. In these cases drilled wells have been necessary to supplement or replace the dug wells. Local residents informed the writer that there has been an increase during the past few years in livestock. This, in turn, has increased the demand for water. A third factor that has stimulated water well drilling in recent years is the concentration of home building in suburban areas out of reach of municipal supplies. The deepening of drainage lines and construction of new drains has undoubtedly lowered the water level in some shallow wells. However, it is believed that many of these wells would not meet the current increased demand for water had other factors remained unchanged. Increased runoff due to deforestation has possibly had minor influence upon the water table but this loss probably would not equal the greatly increased consumption. Recession of a water table may be caused also by decrease in precipitation. Although no records have been kept within this area as to the relationship of rainfall to the ground water level, the fact that less than 5 per cent of the water fed into the Henry County streams is derived from sources outside of the county indicated how closely the water supplies are dependent upon precipitation.

Local ground water supplies in the New Castle area appear adequate for individual suburban wells. However, the prospects for the city for the future are not as promising. If the city continues to grow as rapidly as it has during recent years the present municipal and industrial water supply may have to be supplemented by a surface reservoir or wells located some distance from the city. The same is true, but to a lesser extent, for Knightstown.

Conclusions

Henry County is a headwaters area which depends almost entirely upon precipitation within the bounds of the county for a continual supply of surface and subsurface waters. Municipal, industrial, domestic, and livestock water supplies are derived almost entirely from ground water sources. The principal source of ground water in Henry County is local aquifers in the thick mantle of glacial drift which blankets more than 97 per cent of the county to a depth of 100 feet or greater. Where the glacial cover is thin or composed of impervious clay till, domestic and agricultural supplies of water may be obtained from Silurian limestones and dolomites which underly most of the county. Water in these rocks usually occurs in the upper 20 to 30 feet of the limestones. Geological formations older than Silurian can not be relied upon to yield adequate potable water supplies. Shales and shaly limestones of the Cincinnatian Series (Upper Ordovician), immediately under-lying the Silurian limestones and dolomites, are neither porous nor permeable and, consequently, do not make satisfactory aquifers. The Trenton limestone (Middle Ordovician) frequently yields copious quantities of water, but in general this water is highly mineralized.

It is thought that no actual over-depletion of ground water reserves exists as yet for Henry County as a whole. Ample supplies of water for domestic and agricultural purposes may be secured below a depth of 40 to 50 feet. Municipal and industrial supplies, particularly in the New Castle Area, may have to be derived from wells located some distance from that city or from surface supplies resulting from the construction of a dam and reservoir. Excellent water-bearing gravels are known to exist along Duck Creek about 4 miles a little north of west of New Castle's pumping station.

Local recession of the ground water level in Henry County is believed to be the result of a combination of several factors, the foremost of which is the greatly increased consumption of water for domestic, industrial, and agricultural purposes.

Buried bedrock valleys are known to exist in Henry County. From data gathered in the field and our knowledge of other buried valley systems in Indiana, it is postulated that the buried valleys in Henry County are tributaries of the great Teays system which once crossed northern Indiana from east to west. Wells drilled for water along these valleys in Henry County have not encountered satisfactory supplies of water. The character of the material encountered in these tests suggests that the valleys were blocked by the advance of Pleistocene ice and subsequently were filled with fine silts and clays which are neither sufficiently porous nor permeable to yield ground water consistently.

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Underground Water and Glacial Geology of Scottsburg, Indiana and Vicinity

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Introduction

Early in July 1948 the writer was asked to assist the firm of Poole and West, well drillers, of Scottsburg, Indiana in a search for a larger water supply for the city. The project as proposed by the city required the contractors to provide a well or wells that would furnish 400 gallons per minute of potable water. These wells to be located within five (5) miles of existing water mains.

It is the purpose of this report to record the results of this study including the results of borings made and secondly to describe something of the glacial geology of this part of the Scottsburg Lowland.

Previous Work

In April of 1945, Mr. Fred H. Klaer Jr. of the U.S.G.S. published a "Preliminary Report on Ground-Water Conditions in the Vicinity of Scottsburg, Scott County, Indiana." This report summarizes the "results of several days field investigation" as well as work previously done in an effort to add to the city's inadequate supply of water. The inadequacy of the water supply may be judged from Klaer's statement, "The total quantity of water available was estimated to be 130,000 gallons per day. The average daily consumption in September of 1944 was 172,000 gallons per day with a maximum of 200,000 gallons per day."

The most extensive drilling done in the past was by the Layne-Northern Company of Mishawaka, Indiana. In 1938 this company drilled 41 test wells on which accurate logs were kept and numerous tests were recorded without preserving the logs. Most of the logged wells were put down in the vicinity of Lake Iola at the northern edge of the city but a few were drilled elsewhere which contributed considerably to an understanding of the bedrock topography.

The Present Study

The present study was undertaken with the following assumptions in mind. (1) The Scottsburg Lowland[1] was carved by glaciation. (2) During deglaciation, water from the shrinking ice sheet should have established fairly definite channels in the bedrock, and these channels would have fairly extensive permeable sediments. (3) Since the lowland of the vicinity of Scottsburg is roughly six miles wide, a major stream could be assumed to have done the carving. Its channel sediments would be permeable, extensive and sufficiently continuous to make an aquifer.

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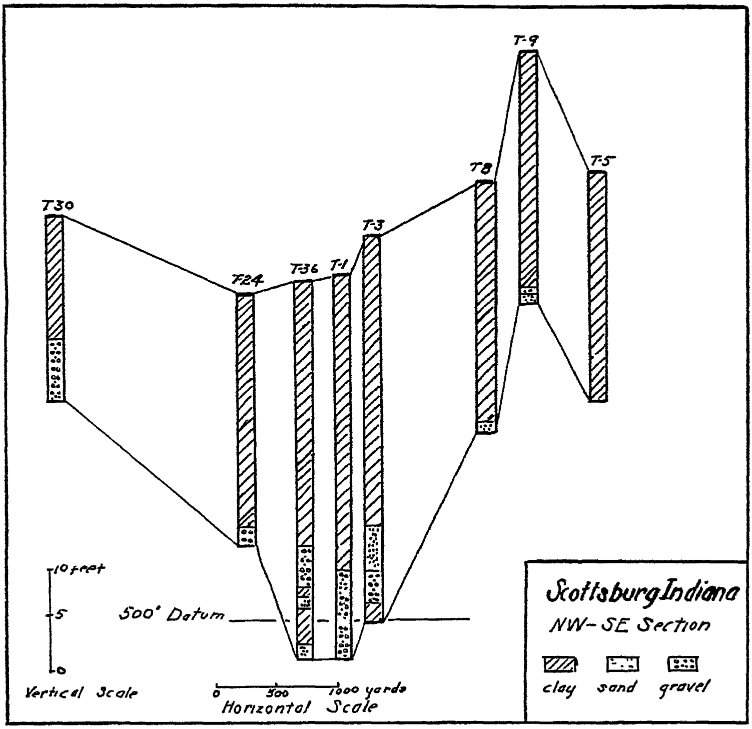
[1] For description of this physiographic division see: "Handbook of Indiana Geology" Pages 80-90. Indiana Department of Conservation 1922.

On the other hand, if such permeable, extensive, and continuous sediments did not exist there was no point in looking for lesser sand and gravel bodies since they could not be expected to yield the 400 gallons per minute of water required by the contract.

Thus the problem resolved itself to a matter of making soundings in the glacial drift in a pattern sufficiently close to encounter any extensive gravels filling a bedrock channel[2].



As a preliminary to this search, the logs of the Layne-Northern Company were studied and two sections made. One trending NE-SW and a second NW-SE as shown in figure 1. These revealed a low in the vicinity of Test T-1.

Just prior to the writers employment on this project Poole and West had recognized this low and had sunk three wells at points marked W2, W3, and W4 on the accompanying map (figure 2). These wells filled with water but, on pumping well W2, the static head was lowered 23 feet and that of well W4 lowered 4 feet. Both wells required three days to recover a normal static level. This slow recovery discouraged further sounding close to the wells since the sand body encountered, though thick enough, could hardly be extensive in view of this rapid drawdown and slow recovery.

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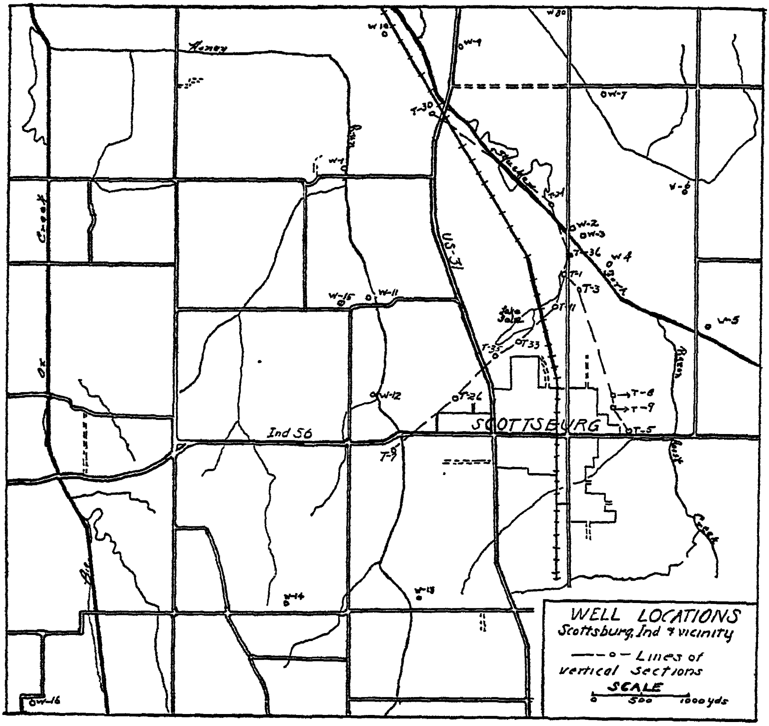
[2] Deep drilling in bedrock was not considered advisable due to the high mineral content of waters usually encountered.



Nevertheless, the valley of Stucker Fork was explored with borings at W-5, 6, 7, 8, 9, 10 (figure 2). These together with Layne-Northern Co. Tests, T-23, 24, 29, 30, 36 proved Stucker Fork did not have an extensive aquifer

Attention was next directed at Honey Run. Beginning in sec. 12, 6E. 3N. tests were made up stream as shown in figure 2. at W-1, 11, 12, 13, 15. None encountered any considerable sand except W-11 which filled with sand and water at 13 feet below surface. This hole was "mudded back" and by keeping a head of water in the hole 3½ feet of water bearing sand was penetrated and 5½ feet deeper bedrock was encountered,—see accompanying logs. Test W-15 sunk 200 yards away penetrated clay and clay only. Other borings in Honey Run yielded similar negative results as did Layne-Northern well T-25.

Thus the stream valleys were eliminated as likely water producers and the uplands were prospected. Borings were made at W-14 sec. 25, 6E. 3N. and at W-16 sec 35, 6E. 3N. neither showed pervious beds. A permanent well of the city T-46 sec. 18 7E. 3N. bottoms on bedrock and yields only a small quantity of water. Tests of Layne-Northern Co. T. 26 (western part of city) and T-40 south of city encountered nothing but clay and were dry.

This evidence was deemed sufficient to eliminate the area beneath the divide as a water bearer and boring was discontinued.

Bedrock Topography

The bedrock in the southwestern part of this area is a gray shale (Borden) the rest is black shale (New Albany). Though both are commonly described as soft shale they are too hard to be cut with an auger. Hence, borings penetrated only to broken rock.

It is possible to contour the bedrock from the 57 borings on which records exist. The Stucker Fork floodplain overlies an elongated bed-rock low with an embayment in the vicinity of Lake Iola. This embayment is the only place where thick sand lenses are encountered.

Glacial History

The region has had two periods of deposition with an interval between during which plant growth flourished,—wood was brought up from test 9,—and others showed a weathered clay with carbonaceous particles at varying depths usually about 6 feet below the surface. The thickness of this weathered peaty zone was usually less than a foot though test W-9 penetrated 3 feet of plant debris and tests W-13 and W-14 had 2 feet of peat and clay. The accompanying logs show the record for all the above.

The hypothesis of a major glacial stream in the Scottsburg Lowland seems untenable for no extensive sand and gravel bars exist. The Lake Iola embayment in the bedrock has a thick sand body (15 feet) but it is not extensive and not continuous.

In view of this lack of evidence of glacial streams it would seem that a glacial rather than a glacio-fluviatile origin of the lowland must be assumed. A possible explanation is found in the adjacent "Knobs" to the west. These "Knobs" (knobstone escarpment) resisted passage of the ice across them and tended to alter the direction of ice movement to parallel their front. Thus the erodable shales adjacent to the "Knobs" were subject to a more severe ice attack than similar shales farther east and hence were more deeply eroded. The bedrock low beneath Stucker Fork may not even be continuous but merely a local variation in rodability of the shale.

The origin of the clay which covers this area and so much of the adjacent Muscatatuck Regional Slope to the east is not clear. Leverett[3] maps this area as loess and such may be the best designation for the material. Nevertheless; it should be borne in mind that columnar jointing, and weathering in vertical cliffs is not present. Nor have land fossils been discovered in the clay.

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[3] Leverett, Frank. "Pleistocene of Michigan, Indiana and History of the Great Lakes." Monography of U.S.G.S. Vol. LIII, 1915. Plate VI.

Summary

A study of the results of nearly 60 wells and borings made in a search for water in the vicinity of Scottsburg, Ind. shows clay covering the bedrock with only a few scattered, discontinuous, thin sand lenses. Thickness of the clay varies from 0 to 40 feet.

An elongated depression in the bedrock exists beneath the Stucker Fork floodplain trending NW-WE. With a conspicuous embayment at Lake Iola.

There are a few widely scattered sand lenses but no other evidence of glacio-fluviatile origin. The origin of the lowland itself at this locality is believed to be due to diversion of ice by the adjacent knobstone escarpment which accelerated glacial action in the soft shales of the lowland. Whether the clay which covers the bedrock is wind or water laid or a weathering product is not determined. That there have been two periods of deposition separated by a period of plant growth and weathering is evident.

Log of Test Wells Drilled and Borings by Poole and West

Scott County, Indiana, July, 1948.

Test: W-1 **boring**

Location: Range 6E. Twp. 3N. Sec. 12; 1750 yds. E. 5 yds. N. of SW corner
Bed of Honey Run
Surface el. 532 ft.

Formations	**Thickness Ft.**
Gravel	2½
Blue Clay	8 and more

Test: W-2 **well**

Location: Range 7E. Twp. 3N. Sec. 17; 505 yds. E. 1300 yds. N. of SW corner.
Surface el. 536 ft.

Formations	**Thickness Ft.**
Clay	13
Sand, Blue Clay	16
Gravel, Sand, Shale	7
Bedrock	—
Total	36

Test W-3 **well**

Location: Range 7E. Twp. 3N. Sec. 17, 645 yds. E. 1285 yds. N. of SW corner.
Surface el 536 ft.

Formations	**Thickness Ft.**
Clay	13
Clay and Sand	16
Gravel	7
Clay	3
Bedrock	—
Total	39

Test W-4 **well**

Location: Range 7E. Twp. 3N. Sec. 17; 830 yds. E. 880 yds. N. of SW corner.

Surface el. 536 ft.

Formations	**Thickness Ft.**
Clay	13
Sandy Clay	16
Gravel	7
Bedrock	—
Total	36

Test W-5 **boring**

Location: Range 7E. Twp. 3N. Sec. 16; 30 yds. E. 240 yds. N. of SW corner.

Bed of Stucker Fork

Surface el. 532 ft.	**Thickness Ft.**
Formations	4½
Blue Clay	10
Muddy Sand	3
Sandy Clay	½
Clay and Broken Shale	—
Total	18

Test W-6 **boring**

Location: Range 7E. Twp. 3N. Sec. 17; 1720 yds. E. 1580 yds. N. of SW corner.

Surface el. 536 ft.

Formations	**Thickness Ft.**
Yellow Clay	7½
Blue Clay	2
Yellow Clay	½
Blue Clay	9
Dark Clay and Shale	½
Bedrock	—
Total	19½

Test W-7 **boring**

Location: Range 7E. Twp. 3N. Sec. 8; 850 yds. E. 840 yds. N of SW corner.

Formations	**Thickness Ft.**
Yellow Clay	7
Peat	½
Blue Clay	12
Dark and Gray Sand	2
Sand and Broken Shale	½
Total	22

Test W-8 **boring**

Location: Range 7E. Twp. 3N. Sec. 8; 400 yds. E. 1640 yds. N. of SW corner.

Surface el. 538 ft.

Formations	**Thickness Ft.**
Clay	19
Sand	½
Broken Shale	—
Total	19½

Test W-9 **boring**

Location: Range 7E. Twp. 3N. Sec. 7; 1130 yds. E. 1300 yds. N. of SW corner.

Surface el. 532 ft.

Formations	**Thickness Ft.**
Yellow Clay	4
Blue Clay	14
Sand Peat and Wood	3
Brown Clay	3
Gravel, Broken Shale	2
Total	26 (Limit of Boring)

Test W-10 **boring**

Location: Range 7E. Twp. 3N. Sec. 7, 350 yds. E. 1350 yds. N. of SW corner.

Surface el. 534 ft.

Formations	**Thickness Ft.**	
Yellow Clay	5	
Blue Clay	21	
Total	26	(Limit of Boring)

Test W-11 **boring**

Location: Range 7E. Twp. 3N. Sec. 18; 230 yds. E. 490 yds. N. of SW corner.

Surface el. 538 ft.

Formations	**Thickness Ft.**	
Yellow Clay	6	
Peat and Clay	½	
Blue Clay	6	
Coarse Sand with Water	3½	(hole "mudded
Blue Clay	3	back to
Clay and Sand	2½	penetrate)
Bedrock		
Total	21½	

Test W-12 **boring**

Location: Range 7E. Twp. 3N. Sec. 19; 210 yds. E. 1325 yds. N. of SW corner.

Surface el. 548 ft.

Formations	**Thickness Ft.**
Clay	18
Broken Shale	½
Total	18½

Test W-13 **boring**

Location: Range 7E. Twp. 3N. Sec. 30; 670 yds. E. 930 yds. N. of SW corner.

Surface el. 565 ft.

Formations	**Thickness Ft.**
Clay	5
Clay and Peat	2
Clay	6½
Sand	3
Blue Clay and Shale	½
Total	17

Test W-14 **boring**

Location: Range 6E. Twp. 3N. Sec. 25; 1405 yds. E. 920 yds. N. of SW corner.

Surface el. 594 ft.

Formations	**Thickness Ft.**
Clay	8
Clay and Peat	2
Blue Clay	7½
Clay and Broken Gray Shale	½
Total	18

Test W-15 **boring**

cation: Range 7E. Twp. 3N Sec. 18; 360 yds. E. 480 yds. N. of SW corner.

Surface el. 548 ft.

Formations	**Thickness Ft.**
Clay	11
Broken Gray Shale	
Total	11

Test W-16

Location: Range 6E. Twp. 3N. Sec. 35; 315 yds. E. 1755 yds. N. of SW corner.

Surface el. 616 ft.

Formations	**Thickness Ft.**
Clay	4
Clay and Peat	1½
Blue Clay	5½
Sand	1
Clay	15
Clay and Broken Shale	9
Total	36

Rainfall Variability

RONALD L. IVES, Indiana University

Introduction

Monthly and annual rainfall are not only not the same in all places, but vary from year to year in a single location. Where the annual variation is not great, as in Indiana, biotic forms and human culture, being somewhat flexible, are able to compensate for most of the variations. Where the variation is great, or the local environment is being worked close to theoretical limits, extensive compensatory mechanisms must be set up, or each deviation of the rainfall from the optimum value produces great biotic and economic hardship. Prior to about 1940, Indiana had land to spare, so that rainfall variability was of academic interest only to all except a few specialized engineers. Today, and probably for all of the foreseeable future, with increasing production costs, and continuing world-wide food shortages, demand for Indiana farm products is increasing, and at the same time present supplies of agricultural and municipal water are being crowded. In consequence, for the average resident of Indiana, rainfall variability has acquired, or will shortly acquire, a definite personal importance.

Rainfall variability is not only not shown, but is effectively concealed, by the standard climatic charts, which customarily show mean monthly temperatures and precipitation, usually computed for "the life of the record," which, at many stations, is more than half a century. Despite this omission, these charts are extremely useful indicators of average conditions. Charts for four stations—Yuma, Arizona; Salt Lake City, Utah; Bloomington, Indiana; and New York City, N. Y., comprise figure 1. Quite obviously, agriculture in Yuma will be productive only of tumbleweeds and guayule unless irrigation is used. By diversion of almost the entire flow of the Colorado River, the once-arid Salton Sink, west of Yuma and climatically similar, has become the fertile and productive Imperial Valley. Similar procedures, but less extensive, have made the Salt Lake area highly productive.

Reference to the Bloomington chart shows that irrigation is not necessary, for most crops, in a statistically normal year, for not only is rainfall plentiful, but it is fairly well distributed through the year. A slight increase in the production of some crops might be possible if a portion of the normally high rainfall of March and April were stored for use during the comparatively dry month of July. Whether such storage is economically desirable under present conditions is questionable.

The mean rainfall shown in these charts is the ordinary average, computed by adding a number of rainfall values, and then dividing the sum by the number of values added. As is well known to meteorologists

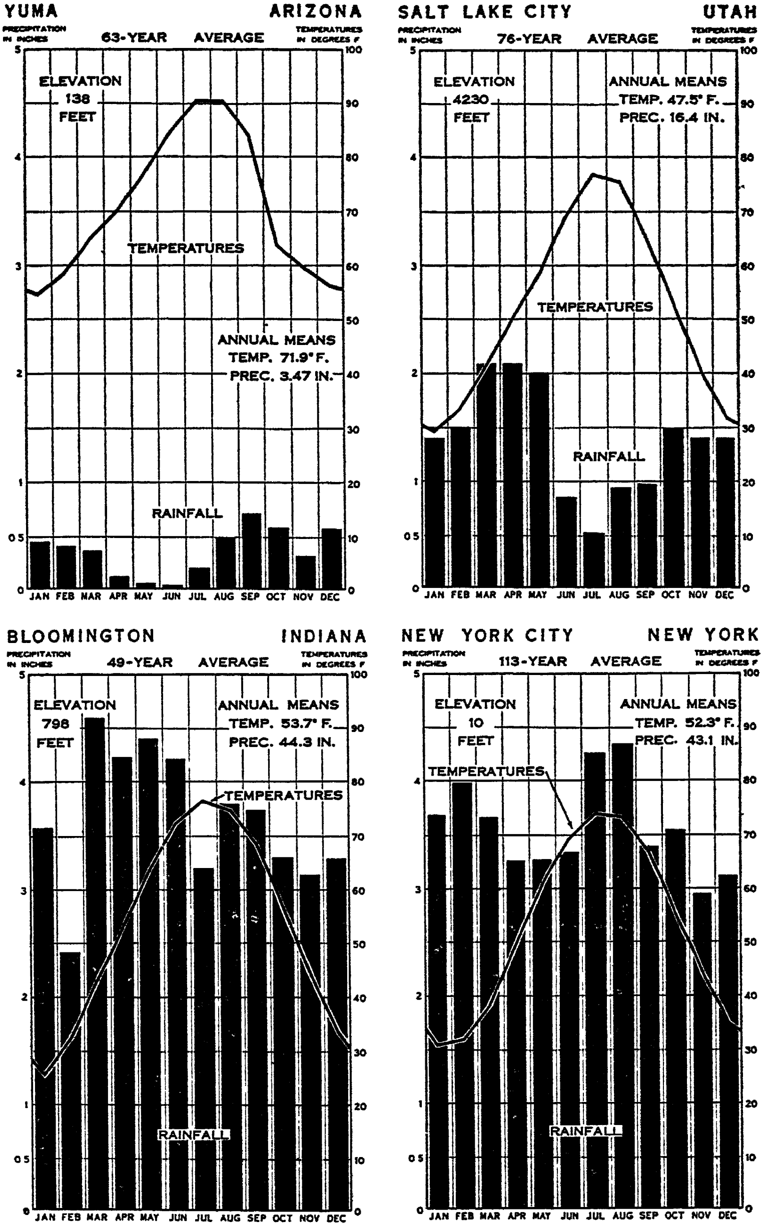

Fig. 1. Climatic charts for Yuma, Arizona; Salt Lake City, Utah; Bloomington, Indiana; and New York City, N. Y.

and climatologists, the mean value, which is also known as the normal, or average, is the value least commonly recorded at many stations.

Rainfall Variability

Rainfall variability, which is not shown on conventional climatic charts, may be of greater biotic and cultural importance than the mean value of the rainfall. If the rainfall in a given area is consistent enough so that each annual planting at least "returns its seed," then a relatively simple cultural organization is possible. Such has been the case in most parts of the "corn belt" of the United States. If, however, rainfall is so variable that a crop is successful only one year in four or five, then a sedentary population must adopt a much more complicated culture, able to store either seed or water, or both, to insure survival through several dry years. In ancient times, the inhabitants of the dry southwest stored seed for long periods; today, water is stored in a series of complicated and expensive reservoirs.

An alternative to the storage of seed or water, or both, is migration over a large area. This is fairly successful where rainfall is erratically distributed, and was used for many generations by the Pima-Papago Indian groups in Arizona and Sonora. Planting of fast-maturing crops was done immediately after a rain, in an area where soil moisture was retained. This "temporale" agriculture, still used in parts of Sonora, is rather surprisingly productive, but is suitable only for areas of low population density.

A "horrible example" of rainfall variability is shown by the Yuma, Arizona, rainfall record, comprising figure 2. Here, the rainfall in some

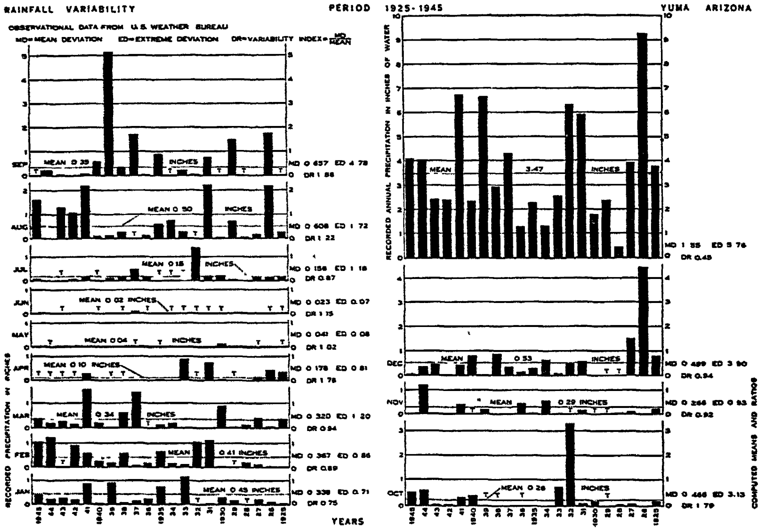

Fig. 2. Monthly and annual rainfall at Yuma, Arizona, for the period 1925-1945 inclusive. Rainfall variability here is extreme.

months (occasionally all from a single "cloudburst") exceeds that for some years. In some years here, without irrigation, even a cactus crop would fail: in others, the cacti would be washed away. Variability at other stations (figure 1) is markedly less[1] the regularity of the rainfall, *in general,* becoming greater as the annual total increases.

Measures of Variability

Rainfall variability may be measured in a variety of ways, most of which have definite and specific uses; none of which fit all needs. Simplest method is to record the actual rainfall at a station, and then to determine the deviation of the recorded value from the cumulated mean for that station. This method is followed by the U. S. Weather Bureau in the preparation of the monthly and annual *Climatological Data* sheets for the various sections.

Although the actual deviations, or the mean of these deviations ("Mean deviation") are of considerable local value, their general value and significance are slight, for an annual deviation of four inches is likely to be disastrous in Yuma, Arizona, for example, but of little significance in Bloomington, Indiana. Several areal studies suggest that mean rainfall deviations are more uniform than mean rainfalls.

In addition, most life forms, upon which our culture and existence are ultimately dependent, can tolerate a considerable variation in water supply, but this variation is commonly a factor of the optimum for that form. Its value depends upon the specific crop, but is commonly from 1.1 to 1.5.

In consequence, the most useful simple measure of rainfall variability is the variability index, computed by dividing the mean deviation in rainfall at a given locality by the mean rainfall for the same locality.

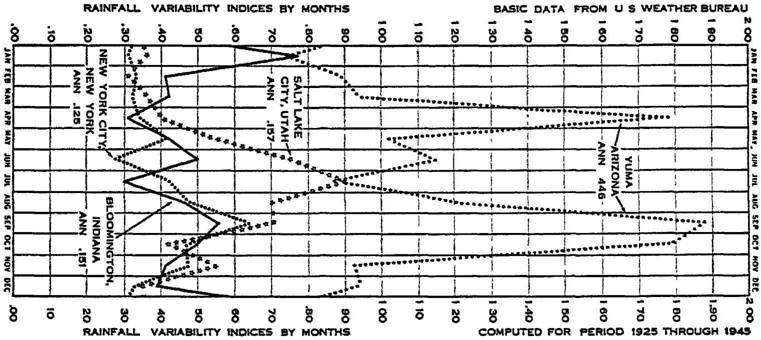

Fig. 3. Rainfall variability indices for Yuma, Arizona; Salt Lake City, Utah; Bloomington, Indiana; and New York City, N. Y.

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[1] Variability at Salt Lake City is discussed in Ives, R. L., Inter-relations of Terrain, Weather, and Climate in the Southern Salt Lake Desert, forthcoming; and that for Boomington, Indiana, is described in a paper being prepared by M. W. Wise, of Indiana University.

Variability indices, computed on this basis, for the four stations graphed in figure 1, are shown in figure 3. With present records and rainfall regimes, this index seems most suitable for extensive studies of rainfall variability.

Where agricultural production depends not only upon immediate rainfall, but also upon some "delayed" factor, such as filling of a reservoir, recharge of an aquifer, melting of snow, or saturation of a subsoil component, simple month-by-month variability indices may not be adequate, and some cumulative system will be found useful. Simplest of these systems is computation of the mean deviation of the rainfall cumulative from a given date, such as Jan. 1 of the year concerned. Many actual problems are even more complex, calling for use of an attrition formula, having the general form K log B, in which both B and K are compound factors, determined from study of local conditions. Comparison of the simple variability index, computed on a monthly basis, with an index computed from values cumulated since Jan. 1, for Bloomington, Indiana, for the period 1925-1945, is included in figure 4. It will be noted that where the rainfall is, or can be, cumulated, by any means, until late spring, the variations in the cumulated amount, and hence in the amount of water available during the growing season, are greatly lessened.

Forecasting Possibilities

In a very general way, it can be stated that in two thirds of the years in any given long sequence (20 years or more), the rainfall will be within the limits of the mean plus the mean deviation, and the mean minus the mean deviation. This approximation is valid for most locations in North America, its dependability declining as the rainfall variability index increases. Theoretically, by use of the Pearsonian *coeffcient of variability*[3], rainfall variations could be evaluated on an actuarial basis, making possible more effective crop insurance at lower cost. Such a coefficient of variability, computed for Bloomington, Indiana, for the period 1925-1945, is shown in figure 4. It will be noted that this is slightly greater than the variability index, previously computed. The difference is caused by the squaring of the deviations, a procedure which gives greater emphasis to larger deviations.

Where the "population" is stable, and the distribution curve is only moderately skewed, the probability of any amount of variability can be determined to any accuracy desired. Most unfortunately, we have no assurance that the "population" (in this case climate) is stable, and much reason to suspect that it is subject to a number of cyclical variations, complicated by fluctuations that now appear to be "pure random." Some progress has been made in correlating climatic fluctuations with sunspot cycles, and integral multiples of the sunspot cycle

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[3] Derivation of these indices is outlined in "Formulae" at the end of this paper.

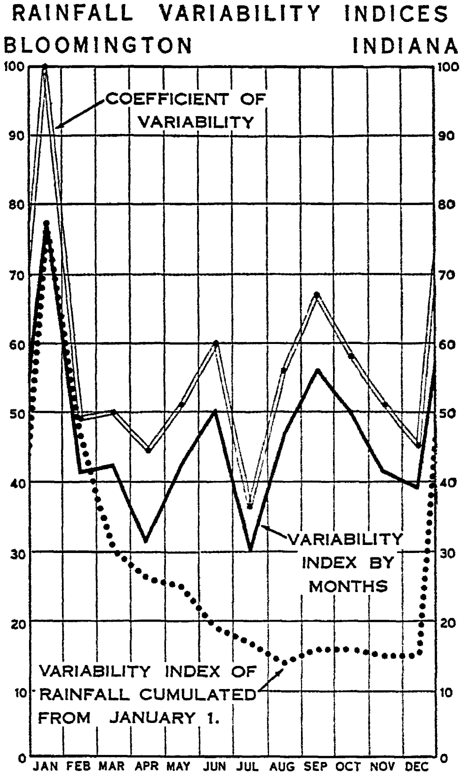


Fig. 4. Comparison of various rainfall variability indices.

(roughly 11 years). Other workers have demonstrated that rainfall in some areas (and only in some areas) bears a definite relation to the solar radiation incident some time previously, not always in the area under consideration. After all of the known and suspected cyclical variations are accounted for, there are still "gremlins" in most rainfall distribution curves. These must be accounted for before rigorous mathematical procedures can be applied to rainfall forecasting.

In addition to the above, most rainfall curves are immoderately skewed, with the absolute maximum value being many times the mean. Not only is the rainfall inconstant, but the amount of skew is not fixed. so that ordinary statistical methods cannot be applied to the problem with any confidence.

Because of the shifting of mean values, use of the standard deviation, and of the Pearsonian coefficient of variability, is not advisable. In contrast, with a slowly shifting mean, values determined by computation of the variability index, in which the deviations are not squared, remain valid for a considerable period, and the errors introduced by slow shifts of the mean cancel out, in time, particularly if the shiftings are of a cyclical nature.

Scatter of the annual values, for the period 1900-1948, for Bloomington, Indiana, is compared with variously computed means in figure

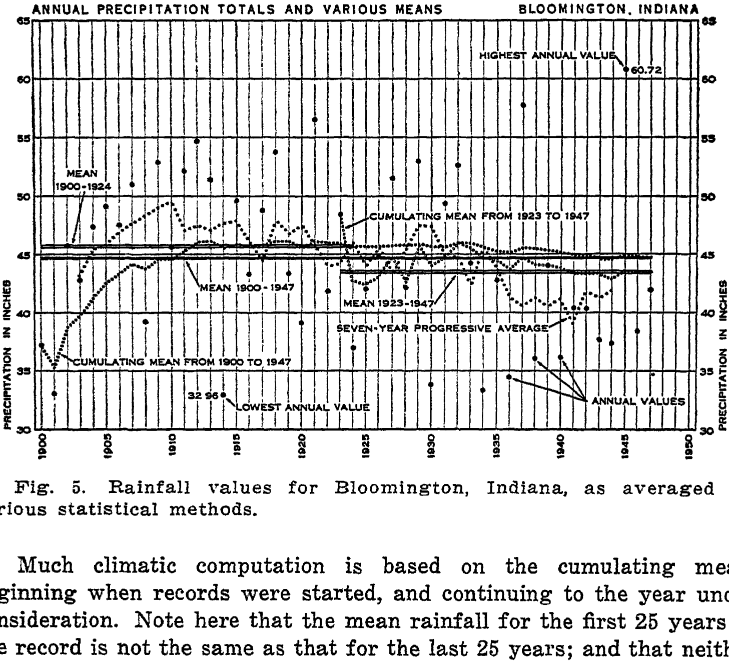


Fig. 5. Rainfall values for Bloomington, Indiana, as averaged by various statistical methods.

5. Much climatic computation is based on the cumulating mean, beginning when records were started, and continuing to the year under consideration. Note here that the mean rainfall for the first 25 years of the record is not the same as that for the last 25 years; and that neither is the same as that for the total record.

The progressive average shown in figure 5 is one of several methods used to detect and predict trends. Here it shows a slight erratic upward trend in local rainfall, following a short period of slightly decreased mean precipitation.

The problem of forecasting, as well as that of formulating general working rules, is complicated by the difficulty of applying a general rule to a specific case. For example, the generalization "rainfall variability increases as the total amount decreases" is quite satisfactory when annual totals of rainfall are considered, but fails miserably when monthly totals are concerned. At the four stations considered in figures 1 and 3, in only one case (Salt Lake City) does the month of minimum rainfall also have the maximum variability; and in no case does the maximum monthly rainfall coincide with the month of minimum variablity. Monthly values of rainfall are plotted against monthly variability indices, for the four stations, in the figure 6.

It has been suggested that, whereas a stable average of annual rainfall totals may be attained at most stations in a period of 35 years

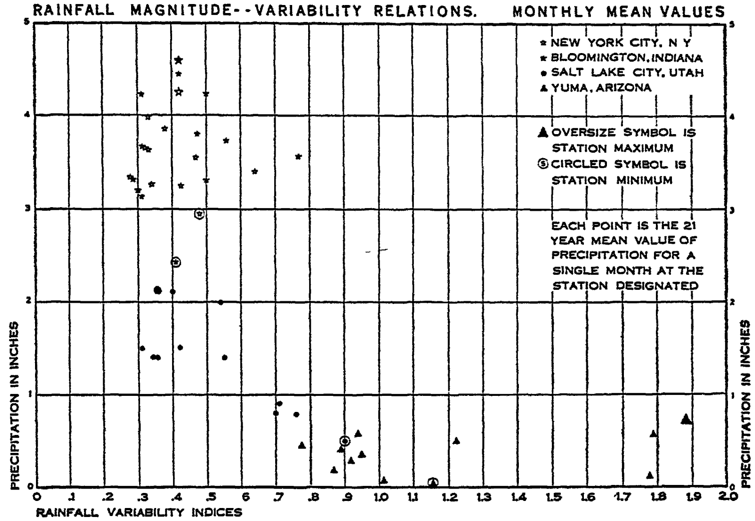


Fig. 6. Rainfall magnitude compared to rainfall variability for the period 1925-1945 for Yuma, Arizona; Salt Lake City, Utah; Bloomington, Indiana; and New York City, N. Y.

or so, the monthly averages will not stabilize until a much longer period has elapsed. Correctness of this suggestion, which is not unreasonable, is hinted at by perusal of the records for London, England. A rigorous check, for a period of about 350 years, for a station where the physical environment is constant, is both very desirable, and completely impossible. There is no such station.

As a result of the multifarious unresolved problems related to cyclical and random climatic fluctuations, possible unidirectional trends, in part "inherited from the Pleistocene ice ages; and the short span of human records and observations; it appears that the more rigorous and valuable statistical methods, such as use of the Pearsonian coefficient of variability, cannot be applied with any hope of correctness to rainfall variability problems at the present time; but that the cruder methods, based on the variability index, are very useful, within their acknowledged limitations, today.

Applications of Rainfall Variability Data

Variability of rainfall is all too commonly considered a problem of interest only in areas of irrigation agriculture. In those areas, rainfall variability is certainly a problem, but nearly every Indiana community is directly concerned with the same problem. Municipal water supplies, for domestic and industrial use, are very greatly affected by cumulating rainfall deficiencies of medium duration (such as 24 months). Before water supplies in many Indiana communities can be regarded as satisfactory, additional construction, to compensate for the effects of both immediate and cumulated water supply shortages, will be necessary.

When the rainfall exceeds the mean value for the period under consideration, the water-disposal facilities are affected. This includes municipal street and sewer departments; flood control works; and erosion control agencies. The problem here becomes quite complex, for the municipal facilities are concerned with getting rid of the water rapidly, whereas the flood control works, as well as the erosion control methods, are designed to retard and stabilize runoff.

Both water storage and water-disposal facilities must be designed to function under a wide variety of conditions, both of excess and scanty water; and to function satisfactorily with a minimum of interference with local water tables. In some instances at least, solution of the problem of flow stabilization has created a new problem of mosquito control.

Both rainfall scarcity and rainfall surplus can be largely compensated for by construction of proper dams, reservoirs, and similar structures, and such structures are costly. Such construction is insurance, and there is always the possibility of overinsurance. If either flood or drought protection costs more than the damage likely to be produced by a flood or drought, there is a possibility that it is undesirable, or "overengineered." In very general terms, water control facilities which permit normal operation when the annual rainfall is within the limits of the annual mean plus or minus twice the annual mean deviation are the maximum that are economically justifiable under present conditions in most areas. Rough probability computations indicate that with such protective measures, normal operation will be prevented by rainfall variations only about once in 20 years.

Conclusions

The foregoing consideration of the problem of rainfall variability indicates that Indiana is located in a region where such variability is not great, and where, in addition, rainfall is adequate for the present economy.

Relatively minor water control works will be able to equalize the annual rainfall distribution sufficiently to permit a slight increase in agricultural production, when construction of such works is economically desirable.

Somewhat more extensive water control structures are already necessary to reduce flood damage, and to provide municipal and industrial water. Many of these works are at present inadequate, and rainfall variability must be considered as they are expanded.

Both overexpansion of water control facilities and overscientific methods of determining rainfall variability must be guarded against, because both are costly errors, leading to overinsurance, and, in most cases, inordinately high tax bills.

FORMULAE

Individual values $= X$

Number of values $= N$

($\Sigma =$ "the sum of")

Arithmetic mean $= \overline{X} = \frac{\Sigma(X)}{N}$

Individual deviations $= x = |X - \overline{X}| = \left|X - \frac{\Sigma(X)}{N}\right|$

Mean deviation $= MD = \frac{\Sigma|x|}{N} = \frac{\Sigma|X - X|}{N} = \frac{\Sigma\left|X - \frac{\Sigma(X)}{N}\right|}{N}$

Variability index $= \frac{MD}{\overline{X}} = \frac{\Sigma\left|X - \frac{\Sigma(X)}{N}\right|}{\Sigma(X)}$

Standard deviation $= \sigma = \sqrt{\frac{\Sigma\left|X - \frac{\Sigma(X)}{N}\right|^2}{N}}$

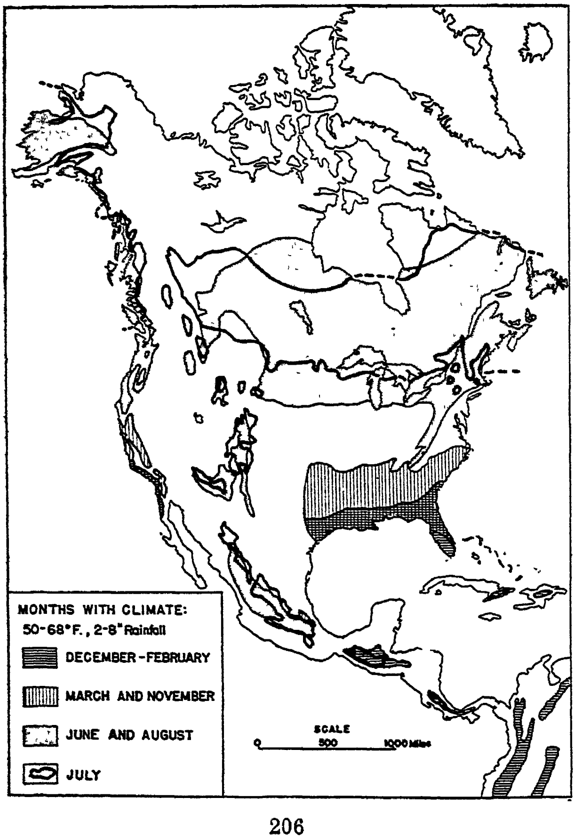
Coefficient of variability $= \frac{\sigma}{\overline{X}} = \frac{\sqrt{\frac{\Sigma\left|X - \frac{\Sigma(X)}{N}\right|^2}{N}}}{\frac{\Sigma(X)}{N}}$

Optimum Indiana Weather Elsewhere

Otis P. Starkey, Indiana University

During World War II our army was called upon to operate under a great variety of climatic conditions and ignorance of overseas climatic conditions often resulted in the assignment of unsuitable equipment to many units. Subsequently the Office of the Quartermaster General established a Climatology Unit which prepared maps showing climatic conditions month by month for each continent. These climatic zone maps have been used by the armed forces and by a few geographers but few business applications have been reported. Here it is suggested that broader civilian use of these maps is feasible and their application to the tourist business is offered as an example.

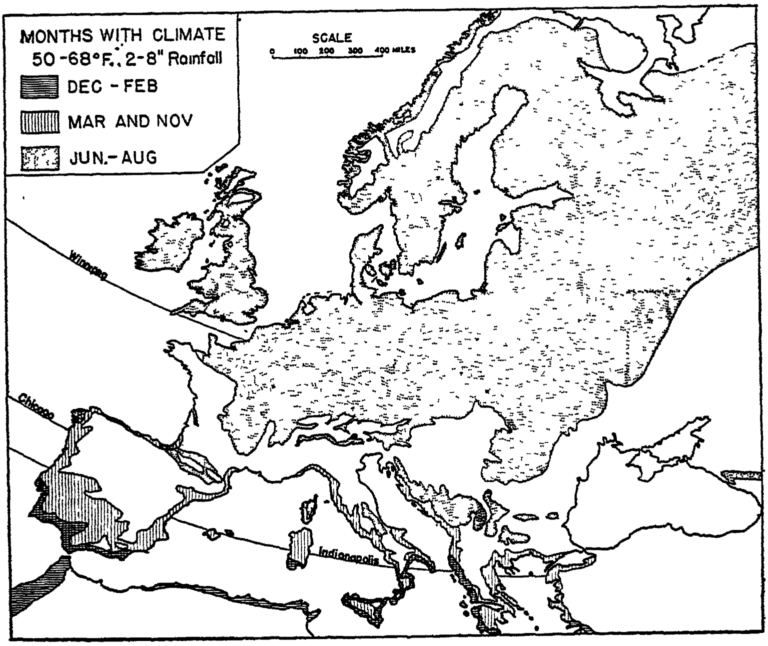
In this hypothetical case let us assume that a Hoosier tourist is anxious to spend a vacation in weather comparable to the best Indiana has to offer. Our tourist, like most of us, prefers the common Indiana



weather of April and May and its autumn counterpart in September and October. At such seasons a medium-weight wool suit, supplemented at most by a topcoat, provides comfortable attire. Statistically such weather occurs with monthly averages between 50° and 68°F. and in Indiana is accompanied by from 2 to 8 inches of rain per month. The climatic zone maps classify such a climate as *mild* and *humid.*

The climatic zone maps make it easy to discover where this, or any other climate, can be experienced each month of the year. The accompanying figures generalize some of this data to show the possibilities open to our hypothetical Hoosier tourist in North America and Europe. Note that these maps do not show where exact duplicates of ideal Hoosier weather may be found: differences in winds, thunderstorms, diurnal fluctuations and the like are disregarded. But the maps do show where clothing and other equipment suitable to Indiana spring and fall weather would be appropriate.

The map for North America (figure 1) offers only a few surprises. Thus the optimum weather occurs in the central American highlands in winter and summer but on the Mexican plateau only in summer. Some of the lands commonly visited by winter tourists fail to meet our tourist's criteria; thus Mexico and much of the American Southwest are too dry and the Caribbean lowlands are too hot. In June and August extensive areas in our country are classified as mild but in July a visit to Canada or a few mountain areas is necessary to avoid the heat and to approximate Indiana's late spring.



The Europe map (figure 2) shows that only narrow areas around the Mediterranean have mild humid weather in winter. Even the presence of these areas is noteworthy when it is observed that the parallel of Indianapolis extends through the center of the western Mediterranean Basin. In summer most of Europe has ideal weather from June to August and this weather is so equable that it is unnecessary to differentiate July from June and August as in North America. The relative freedom of western Europe from extreme heat is explained by its latitudes which are similar to those of Canada.

With the basic climatic zone data, other maps to fit other requirements could easily be constructed. Maps showing the distribution of dry, mild climates would be of value to those suffering from sinus. Maps showing the distribution of warm, dry climates would be of interest to those suffering from colds and rheumatism. By applying this climatic data in such ways, geographic patterns take on practical significance and change from mere academic wisdom to aids in the planning of human activities.

Soil Conservation in Action

G. David Koch, Indiana State Teachers College

One of the most serious problems confronting the nation is that of soil erosion. During the past decade it is heartening to learn that farmers and other individuals are awakening rapidly to the growing menace of soil losses. In most parts of our country steps are being taken to counteract the erosion evil. Farmers, with the aid of local, state, and federal agencies are putting into operation means by which soil conservation will succeed.

The first step in establishing any soil conservation program is that of interesting the farmer in the plan and proving to him the economic validity of soil conservation practices. This first hurdle is best crossed by the actual demonstration of soil conservation procedures and the results obtained by careful farm planning.

Among the problems that need most to be demonstrated are those of water, soil and crop management.

This paper is a report of a soil saving demonstration which was held on a Vigo County, Indiana farm last September.* The farm is 160 acres in size and the physical characteristics are typical of upland farms in that part of Vigo County. The topography is rolling with slopes ranging from two to fifteen per cent. However, at least three-fourths of the farm has a slope below five per cent. The soil is silt loam, with a light grey topsoil, fine textured and medium acid in reaction. As shown in table 1, the cultivated soil has an average p.H. of 6.5, which is quite near the normal p.H. of 7. The present p.H. in the tilled fields is the result of applications of lime during the past five years.

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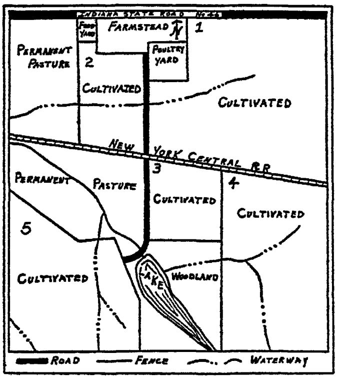
* The farm is owned by Dr. H. M. Bratt, of Terre Haute, and is the first farm east of Riley, Indiana on the south side of State Road No. 46.

The pasture land, where no lime has been applied, has a much greater acidity (table 1).

TABLE I. Chemical Condition of the Soil in 1948 by Fields.

Field	p.H.	Phosphate	Potash
1	6.4	Low	Medium
2	6.5	Low	Medium
3	6.4	Medium	Very high
4	6.6	Low	High
5	6.6	Low	High
Pasture	5.8 or below	Very low	Low

Of the total area of the farm, 104 acres are under planned cultivation, 27 acres are in permanent pasture, 10 acres are in woodland and the remaining 19 acres are occupied by farm buildings, feed lots, poultry yards, a railroad, and roads. The arrangement of the farm, as it was on demonstration day, is clearly illustrated in figure I.



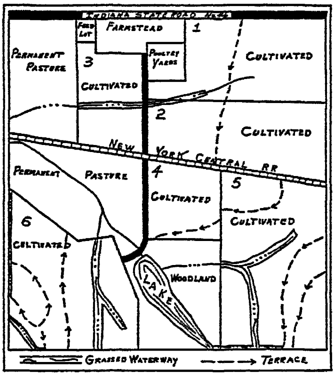


Fig. 1. The arrangement of the farm prior to Demonstration Day.

Fig. 2. The farm map with terraces located, as constructed and the location of proposed grassed waterways.

The farm has been under a planned crop and fertilizer program since 1943. During this five-year period all boundary and all cross fences have been made hog-tight. The barn has been remodeled and a concrete feeding floor constructed. The farmstead is also equipped with a running water system. Further improvements are under consideration. During the past five years, since the farm has been under the present ownership, the raising of livestock has been the primary interest. Plans call for more emphasis on livestock during the next five year period.

Losses, due to water erosion, are evident at numerous points on the farm. In field number four, figure I, a gully a foot deep and one to two feet wide extends up the drainage way from the wood tract. It has been cut back into the field for at least 100 yards. Thin topsoil is also evident on the steep slopes in the southeast part of field four.

In field five numerous evidences of erosion are present. In the southwest corner steep slopes have aided the development of several short gullies. These gullies have impeded the use of farm machinery. On the east side of the same field a drainage way exists. Below the junction of the two drains, a wide flat bottomed runway has been eroded. The slopes of this drainage way are steep, being 10-15%. Sheet erosion is excessive here. On the day of the demonstration, this erosion was clearly seen. The light yellow soil of the steep slopes contrasted sharply with the darker soil on the bottom of the runway and adjacent uplands.

The drainage line crossing field 2 is also actively eroding a small gulley, which if left uncontrolled would soon eat its way back into field one. The wooded area is well under control because of the permanent stand of trees. The lake is artificial.

To develop a long range farm plan, the first step is that of making an inventory of the farm. This includes an anlysis of the soil, measure-

TABLE II. Crop and Fertilizer History by Fields.

FIELD	1943	1944	1945	1946	1947	1948
No. 1 Crop Yield Fertilizer applied	oats 50 bu.	beans 12 bu. 200 lb. 2-12-12*	wheat 20 bu. 300 lb. 2-12-12	clover 1 ton	corn 80 bu. 1000 lb. phosphate	corn 400 lb. 3-12-12
No. 2	rye 10 bu.	clover pasture	clover pasture	corn 70 bu. 500 lb. 3-12-12	beans 26 bu. 100 lb. phosphate	wheat 30 bu.
No. 3	rye	rye 10 bu.	clover 1½ ton	corn 60 bu. 200 lb. 3-12-12	beans 26 bu. 1000 lb. phosphate	wheat 30 bu. 400 lb. 3-12-12
No. 4	corn 20 bu. 200 lb. 3-12-12	pasture	beans 12 bu.	wheat 12 bu. 250 lb. 3-12-12	clover 1½ tons	clover pasture 100 lb. phosphate
No. 5	beans 10 bu.	corn 20 bu. 400 lb. 3-12-12	beans 12 bu.	oats 15 bu.	sweet clo. pasture	sweet clo. pasture

* Proportionate parts of nitrate, phosphate and potash respectively. Each field has received 6 tons of lime during the period.

ment of steepness of slopes, extent to which erosion has taken place and the available water supply. Once the inventory has been made and carefully analyzed the conservationist is then in a position to offer plans for future farming practices. Such practices include planned crop rotations, gully control, sheet erosion control; exclude over-grazing and over-cropping. Among erosion control measures are grassed waterways, terraces, and contoured cultivation.

Crop rotation and fertilization have been followed during the past five years on the farm herewith discussed. The results are set forth clearly in table II. The table includes the rotation plan, yields, and fertilizer applied for each field on the farm. A study of the yields shows a steady increase in production, especially during the past two years.

However, continued loss of water and subsequent soil erosion, during the five year plan, were evidence that crop rotation and fertilization were insufficient for complete control. Consequently a new five year plan has been established. In addition, the building of terraces and grassed waterways are included in the new plan.

An examination of figure II and table III shows the proposed arrangement of the farm and the proposed crop rotation. It may be noted that field 1 has been divided into two parts.

TABLE III. Proposed Crop Rotation by Field 1949-1954 inclusive.

FIELD	1949	1950	1951	1952	1953	1954
No. 1	oats & alfalfa	alfalfa	corn	beans	wheat	alfalfa
No. 2	beans	wheat	alfalfa	alfalfa	corn	beans
No. 3-4	clover	corn	beans	wheat	alfalfa	alfalfa
No. 5	corn	beans	wheat	alfalfa	alfalfa	corn
No. 6	wheat	alfalfa	alfalfa	corn	beans	wheat

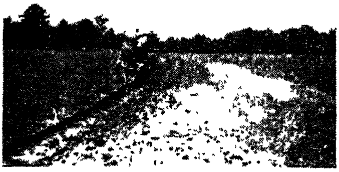
From table III one learns that fields 3 and 4 will be utilized for the same crop. The permanent pasture will remain as such, as will the woodland plot. All of the drainageways that cross cultivated fields will be grassed. Another sodded waterway is to be added along the south line of field 5. It will be seen that each of these grassed waterways drain into either a permanent pasture or the woodland plot, a logical and proven practice. Each of the sodded drains will check gullies now present or potential. None of the sodded drains had been constructed on demonstration day.

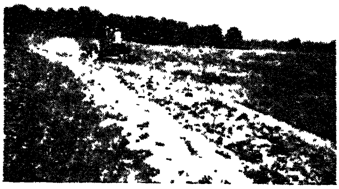
All of the terraces shown in fields 5 and 6 were constructed on demonstration day. Preliminary surveys and lines for these terraces had been made and drawn prior to the demonstration. The terrace across fields 1 and 2 has been in operation for a year. Since field 3 will be in red clover until 1950, table III, the construction of the terrace across it will be postponed until that year. Each terrace empties into a grassed waterway or land permanently out of cultivation. The railroad company granted permission to drain the terrace across fields 1 and 2 into the right of way.

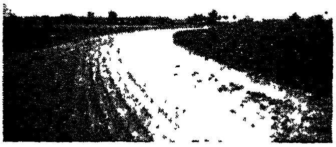
From the proposed crop rotation plan, table III, it is noted that alfalfa, a new crop to the farm, will play an important part in the rotation system. Alfalfa and sweet clover will be depended upon to aid materially in replenishing nitrogen, a chemical used heavily by corn. Since livestock will be the major interest, alfalfa will also furnish needed forage for winter feed.

Alfalfa is recommended over red clover on this farm chiefly because it is a deep rooted legume. Although the soil is low in phosphate, Table I, it is sweet enough to grow alfalfa successfully. Addition of phosphate and potash through commercial fertilizers will aid in securing and maintaining a good stand of alfalfa. Since in most cases wheat precedes alfalfa in the rotation, Table III, the grain will be the "nurse" crop for the legume.

All cultivated crops are heavy users of soil fertility. A seventy bushel corn crop removes about 70 pounds of nitrogen, 28 pounds of







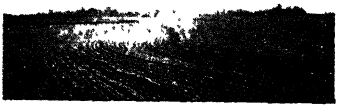


Fig. 3. View in farmyard of Bratt farm just before field trips began.
Fig. 4 Plowing in a terrace. Special auger moleboard plow in use.
Fig. 5. Plowing in a terrace. Common moleboard plow in use.
Fig. 6. A completed terrace in field 5.
Fig. 7. A completed terrace in field 6.

phosphate, and 32 pounds of potash per acre. A twenty-five bushel soy bean yield, harvested for grain, needs 88 pounds of nitrogen, 20 pounds of phosphate and 38 pounds of potash. The bean plant of course secures much of its nitrogen from the air.

The above data means that, in order to secure satisfactory yields and at the same time maintain or improve soil fertility it will be necessary to apply some commercial fertilizer. However, whenever possible, green manure and barnyard manure should be utilized to the best advantage. That is, after all, Nature's way.

On demonstration day flat bed trailers pulled by tractors, furnished means of transportation over the farm for the visitors, figure III. During the morning, the visitors were shown the plows, in operation, building the terraces, figures IV and V.

After lunch, served by a local women's organization, those present enjoyed a chalk talk by an outstanding proponent of soil conservation. After the speech, transportation was again furnished those who desired to observe the completed terraces, figures VI and VII.

Although a farm under complete soil erosion control was not demonstrated, the project was stimulating. The results of a planned five year rotation were shown, terraces to control runoff and sheet erosion were constructed and the projected grassed waterways to control gullying were located. The fact that over seventy-five percent of those present returned to the fields in the afternoon for a second look revealed their interest. It is believed that the demonstration will lead the way toward the formation of a Soil Conservation District in Vigo and adjacent counties.

A Study of the Cucumber Industry at Terre Haute, Indiana

ROBERT RUDD, Indiana State Teachers College

The largest greenhouse in the world with one central heating plant is located at Terre Haute, Indiana. Davis Gardens, as it is known to the local populace, started from two one-acre greenhouses in 1914 and today has 35 acres under glass with an actual growing area of 1,020,000 square feet. The difference between this figure and the former one is due largely to the fact the greenhouse proprietor counts the sides, ends, and roofs of the buildings in totalling acreage under glass. Of the total growing area, 33 acres are used for growing cucumbers, while the remaining two acres are used for the production of tomatoes. The latter crop is grown on an experimental-commercial basis. Experiments are being carried on with various types of cultures, hydroponics mainly. At the same time, production is maintained at a commercial rate. During the height of the growing season approximately 2500 pounds are picked daily. Cucumbers are grown entirely on a commercial scale. From the 15th of December until about August 10th an average of 2000 dozen fruits are picked daily. This industry has grown to such proportions that it is a major source of hothouse cucumbers for the great vegetable distributing warehouses in Boston, Cleveland, Detroit, Chicago, and other main distribution points in eastern United States.

Location

A considerable amount of geography was employed in the original selection of the site for this unique but definitely successful enterprise. Many factors must be considered in locating a greenhouse. First of all, the latitude should be such that the greenhouse can produce for a considerable period of time before and after field production is possible in that locality. Location should be far enough north so that the normal growing season is relatively restricted; yet care must be taken not to locate so far north that excessive costs on items such as fuel will materialize.

An extremely important factor is that of markets. Not only should a good market be available in the immediate vicinity, but access to other markets through suitable transportation facilities is important. Orginally most of the shipping of the product was done by rail, consequently access to several large railroad systems was necessary. Four large railroads have routes through Terre Haute making it a good location for that reason. The New York Central, Pennsylvania, Chicago and Eastern Illinois, and Chicago, Milwaukee, and St. Paul railroads have a combined coverage of considerable market area. Emphasis later shifted to shipping by truck, and today the majority of Davis Gardens produce is carried by a truck fleet. The "crossroads of the nation,"

U. S. 40 and U. S. 41 pass through Terre Haute and add to its desirability as a shipping center.

In choosing a greenhouse location, a nearby source of suitable fuel is essential. At the time Davis Gardens was established the bituminous coal of the Indiana coal fields seemed an excellent source of supply. When the average tonnage used per year is realized, the desirability of a very close source is apparent. An average of 20,000 tons are burned annually. Freight costs from the Mount Pleasant Mine four miles from Davis Gardens and from the Blackhawk Mine ten miles away are not nearly the factor they would have been in a less suitable location. A major fuel-saving item is sunlight. The importance of sunlight may be more thoroughly realized when the fact is considered that on a sunny day, even though the air outside has a temperature near 0°F., the heat may be turned off entirely for the several hours that the sun's rays are most direct. Water vapour in the enclosed air of the greenhouse condense on the glass readily; and, after running into cracks around the glass plates, it freezes on contact with the air and effectively seals the leaks. Other conditions, a calm day for example, are necessary for such fuel saving opportunities; but sunlight is the major factor. In considering this point Weather Bureau records over a considerable number of years were consulted for the percent of possible sunshine during the so-called "dark months." Figures from the U. S. Weather Bureau Bulletin list 42% of possible sunshine for December, 45% for January, 48% for February, and 53% for March in Terre Haute. Mean normal temperatures are important also, of course, in fuel consideration. From the same publication the figure for Terre Haute in December is 32.5°F., January is 28.7°, February is 31.3°, and March is 40.6°. No one particular item of location is sufficient; many must be considered before a decision is made. Certainly in this instance many major items combined to make the present location desirable. Other factors (source of fertilizers, labor supply, type of

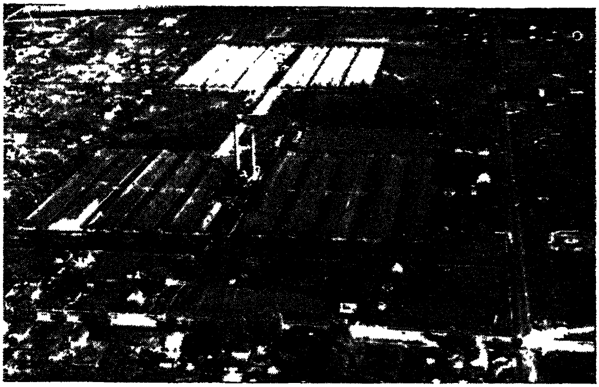


Fig. 1. Aerial view of Davis Gardens.

labor) will be referred to that perhaps are not major ones; still their combined effect is one of aiding rather than deterring.

Heating

Mention was made earlier that Davis is the largest greenhouse in the world with one central heating plant. Other greenhouses have larger area under glass but heating is accomplished through several small heating plants. At Davis Gardens the heating plant consists of four boilers, two with a 500 horsepower rating each and two with a 600 horsepower rating. When the plant was built, stoker size coal was considerably cheaper than ordinary lump. Since the advent of the home stoker relative prices of stoker coal and lump coal have changed; and it may soon be cheaper for Davis to install a crusher so that lump coal, some of which is cheaper, can be used. Fueling is accomplished by Babcock and Wilcox chain grate stokers. A low pressure steam heat system is in use and steam at 125 pounds per square inch is conveyed from the heating plant to distribution points from whence it is further distributed into the various greenhouses. This particular pressure is used since it provides approximately as dry a steam as is feasible. The longest push is one of 1000 feet to one of the distributing points in a 12 inch pipe, or header. Inside the greenhouse the steam enters in low pressure headers, and is conveyed into a series of coils, some along the sides, others near the roof and in the center of the building. Temperatures in the greenhouse are regulated very carefully to secure optimum growing conditions. A night temperature of 66°F. is maintained which varies from the day temperature. Even day temperatures vary according to whether the day is cloudy or sunny. It is of interest to note that on sunny days a temperature of 85°F. is maintained. On cloudy days the temperature is held at 75°F. since less photosynthesis occurs, and higher temperatures cause the vines to stretch. The greatest foe of even temperature maintenance is a cold, windy day. Rapid movement of cold air about the greenhouse buildings constantly robs the area of heat. In a 24 hour period on such a day 250 tons of coal may be consumed. In contrast 100 tons are burned on a calm day with the same outdoor temperature.

Cucumber Culture

Producing cucumbers at a rate of 2000 dozen a day is something that requires considerable planning and careful methods. From the seed to the final product, established practices are maintained in the care and growing of the cucumber plant. Many of the procedures have originated in the experimental plots at Davis Gardens. The cucumber seed is sown about October 15th in a specially prepared seed bed made of compost soil and sand. This growing medium is not as rich as the soil into which the seedlings will be later transplanted. Sowings are staggered, about 20,000 a day being an average sowing, so that too many of the seedlings will not require transference into the pots at the same time. On the third day following the sowing, most of the first group of plants have attained the inch and one-half height required for potting. The plants are maintained in a special propagating house from the time of sowing until two weeks after potting. The seedlings are then planted in the area where they are to bear fruit. Use of a central propagating house for sowing and care of the young seedlings eliminates the problem of very careful temperature regulation throughout the entire greenhouse area as well as cutting fuel costs. During the two weeks potting period careful check is kept on the seedlings, and those which fail to show satisfactory progress are eliminated. This measure insures a majority of top quality plants and makes unnecesary constant replacement of plants that fail at various intervals after final planting. The growing soil used is a sandy loam with fairly high humus content. During the growing season of a crop, approximately 200 tons of manure are used per acre. When total acreage is considered it is realized that location not too far from a source of fertilizer is desirable. The Chicago stockyards, an ample source, are not too far from Terre Haute and the rail connections are good. Some 200 carloads are used during a normal growing season by Davis Gardens.

Of interest too is the preparation of the growing area. Many problems that later might arise are eliminated by careful methods of sanitation and sterilization. About August 10th preparation for the fall crop begins. Sulfur is burned in the growing areas to dry up the vines of the previous crop. All vegetation is removed from the beds and burned in an outside area. The soil in the greenhouse is subjected to roto-tilling. A foot beneath the surface of the soil, a four inch drain tile has been laid in all the growing beds. After covering the soil with canvas, live steam is blown through the tile until the temperature of the soil is brought to 200°F. This method is believed to take care of any plant diseases, plant or insect life present in the soil. After being subjected to the high temperature for some time, the soil is found to have an extra-ordinarily high concentration of salts near the surface. Overhead sprays are employed to re-distribute the mineral through the soil more thoroughly. When this has been accomplished, manure is applied to the growing area and sprayed repeatedly with D.D.T. to eliminate the fly menace. In this prepared area the two week old seedlings are planted about November 1st. Various methods of cultivation, heading and securing a maximum number of laterals in a given length of stem, occupy the worker's time from planting till picking commences. Application of fertilizers is held to a fixed schedule during the period of cultivation and while the plant is bearing fruit. In addition to manure considerable quantities of commercial fertilizer are used. Commercial fertilizers used include muriate of potash, acid super-phosphate, and sulfate of ammonia. Minor elements such as copper, boron, zinc, and manganese are added to the soil at two or three year intervals. The plants are given a start toward climbing wire trellises which extend up the sides of the greenhouse and then horizontally toward the center where they join other structures originating in beds nearer the middle of the building. Since the cucumber plant is a vine, little difficulty is experienced

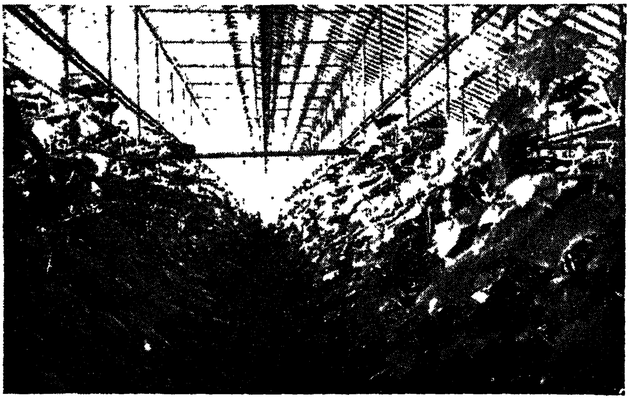


Fig. 2. Inside view of the Cucumber Greenhouse.

in keeping the plant growing upward. There are several reasons for this procedure: it causes more of the plant to be exposed to sunlight; it keeps the cucumbers off the ground where they become discolored or are subject to softening; and it provides a maximum growing area for a given amount of space. The first cucumbers are ready for picking about December 15th and within a month the average figure of 2000 dozen per day is usually reached.

Tomato Culture

The tomato cultures at Davis Gardens are of interest for several reasons. As was mentioned earlier, tomatoes are grown partly on an experimental basis. Work with hydroponics is carried on with the idea in mind of using it on a large scale when minor problems are eliminated. Two types of culture are used: the sub-irrigation type, or gravel culture, and the constant flow type, or water culture. The sub-irrigation type at Davis Gardens employs a water-tight growing bed six inches deep and three feet wide filled with some aggregate such as gravel or haydite, a cinder-like material. A half tile forms an inverted trough in the center of the bed under the aggregate. The bed is so constructed so as to have one end slightly lower to facilitate drainage. Water, containing plant food, is pumped through the tile several times daily, the number dependent upon the type of aggregate and the stage of plant growth. The object is to pump water into the bed until it reaches the upper level of the gravel and then allow it to drain leaving some of the nutrients in the aggregate where it is available to the plant. In the case of water culture, no aggregate is employed. The plants are supported by structures above the water beds and the plant roots are merely suspended in the solution. Care must be taken to keep the light from reaching the roots, and canvas or a similar covering may be suspended just above the water level as a preventative to the growth of algae on the roots. This method differs from the sub-irrigation method also in that the water is

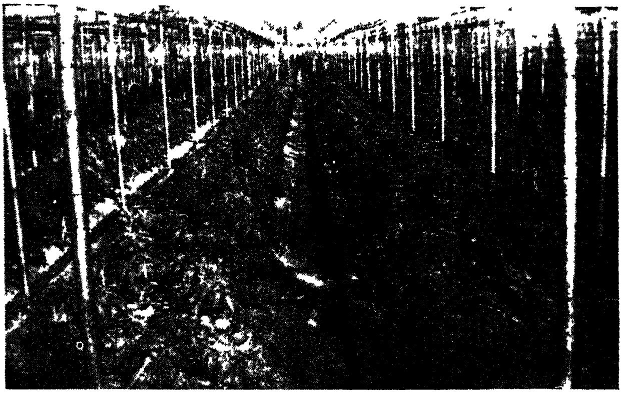


Fig. 3 Hydroponics beds at Davis Gardens. Gravel culture at left and water culture at right.

constantly flowing rather than being changed at intervals during a given time period. The same nutrient solution is used over and over with periodic analyses being made to see that a sufficiently rich solution is maintained. The water culture employs the same nutrient solution as the gravel culture at Davis Gardens. The food itself is composed of all the major elements including calcium, magnesium, nitrates, phosphates, and potash with minor amounts of such elements as iron, copper, and boron. Formulas for the solution used at Davis Gardens were obtained from Purdue University.

Planting and potting methods used are similar to those used in starting the cucumber plant. One of the problems of tomato raising is the setting of the first hand, or causing the first cluster of tomatoes to form. To facilitate the early setting of the hand, the first two clusters of blossoms of each plant are sprayed with a hormone, indole-butyric emulsion. The rest of the hands are set by the workers daily tapping the plant which shakes the pollen loose and facilitates fertilization. Since both the stamen and pistil are present in each bloom of the tomato plant, fertilization is easily thus accomplished. The tomato plant, however, is not the climbing type vine that the cucumber is; consequently, the growing ends of the plant must be repeatedly wrapped around vertical cords which are attached to overhead structures. Conservation of space and presentation of more fruit to sunlight are basic reasons for this type of growing structure. Two crops of tomatoes a year are produced. The first yield is secured from April 1st to July 15th and the second crop from September 1st to December 1st.

In contrasting the products of the two hydroponics beds and those of a soil culture similar to that used in growing cucumbers, several facts come to the fore. The sub-irrigation method, as used at Davis Gardens, requires a shorter growing season, produces a higher yield, and is less costly than either the soil culture or the constant flow culture. Irrigation in the case of the constant flow culture requires 2½ times the quantity of solution since it is a constant flow proposition, and the pumps are operating 24 hours a day. This is a major item of cost in the latter type culture. The quality of tomatoes produced under each culture was so nearly the same that this factor was discounted.

Problems

Problems encountered in greenhouse work are many and varied but those of chief concern are plant disease and insects. The major factors which have been successful in combatting these two hazards are sanitation and sterilization. Preventative measures include fumigation before and after each crop with sulfur and azo-benzene. During sowing and potting periods all materials, insofar as possible, are sterilized and a high degree of cleanliness is required of the workers. Elimination of weeds in grounds between and surrounding greenhouses has been found to aid considerably in pest control. The red spider, a type of mite, is the insect that causes the most trouble at Davis Gardens. Preventative methods have been mentioned. Whenever a leaf is found that has been attacked by the insect, it is pinched off, taken outside, and burned. The area from whence the leaf came is then subjected to spot spraying with hexa-ethyl-tetra-phosphate. If a cluster of spots appear, the area is marked off and thus transference to other plants is held to a minimum. Azo-benzene is applied to the heating pipes in the area and thus is dispersed to the plants. Other insects that constitute problems are the aphid, thrip, and the cucumber beetle. The latter becomes a real menace usually late in the spring. A juice sucking insect, the beetle impregnates the plant with a type of bacterial wilt at the same time it is sucking the plant juices. D.D.T. has been found to be effective against this insect and is applied with the aid of aerosol D.D.T. bombs. Not all insects are effectively controlled with D.D.T. however. To combat the aphid and thrip, Davis Gardens use nicotine pressure cans. These instruments consist of a can with a restricted opening and containing nicotine mixed in a powder. When ignited the powder creates tremendous volumes of dense smoke clouds which contain the nicotine.

In controlling plant disease, prevention by sanitation and sterilization are foremost. Whenever a plant becomes diseased, it is removed and destroyed. The area must be isolated since it is very easy to spread some types of plant disease. Powdery mildew is probably the greatest enemy as to cucumber plant diseases at Davis Gardens. It is a mold that appears on the foliage and stems, and is caused mainly by high humidity and stagnant warm air. Sulfur applied to the steam pipes is effective in dehydrating the air and killing this trouble maker. It has been found that a good principle to follow is: keeping down insects keeps down plant disease too.

Distribution

Produce from Davis at Terre Haute is distributed throughout a market area from the Mississippi River to the east coast, and the services of an entire truck fleet are required to keep warehouses from

Canada to the southland supplied. A second plant at Davenport, Iowa in conjunction with one at Aurora, Illinois ships to the western areas. Timing involved in these shipping operations is important for several reasons. The product is a perishable one and delays are usually costly. Then too, as is true of many such products, changes in prices are often sudden; and, though the change per cucumber may be small, the total change on a truckload is considerable. The value of one truckload often exceeds $10,000. Shipments in the early part of the season are usually to the New York area and Boston. A short while later Chicago, Cleveland, Detroit, Syracuse and others are added. Davis cucumbers have been shipped to Europe on occasion, but the producer's themselves did not do the shipping. Distribution from the large eastern wholesale houses was responsible for overseas shipment. It is believed, however, by Davis Gardens that their product entered the African continent under rather novel circumstances. A Davis official, in chance conversation with a fellow traveler, mentioned the company by which he was employed. The other traveler, an Army officer, asked if it was the same company that was concerned with cucumber raising. It developed that the officer had been in charge of one of the first supply waves to come ashore during the North African Campaign, and he had remembered the large volume of Davis cucumbers that were present in those supplies since they seemed an odd item of war material. It is possible that their purpose was to provide an item of freshness to what perhaps was otherwise rather drab food.

On the occasion of Will Rogers' visit to Terre Haute, the great humanitarian was conducted through Davis Gardens as a part of his seeing the interest spots of the city. Upon conclusion of the tour he is said to have remarked, "Well, I had to come all the way to Terre Haute, Indiana to find out there were people that grew cucumbers on purpose."

Notes on the Size, Distribution, and Growth of Indiana Cities

THOMAS FRANK BARTON, Indiana University

The size of the cities in this article will be based on the 1940 census. The writer plans to prepare a paper comparing the size of Indiana cities of 1940 with that of 1950 as soon as the statistics become available.

Size and Distribution

Our state's cities are characteristically small. There are 100 political units with populations over 2,500. Of these, nearly one-third or 32 have less than five thousand; and 33 more have a population of five to ten thousand. By combining these two groups, we have sixty-five cities or sixty-five per cent of them with a population of less than ten thousand. There are 15 cities that range from ten to twenty thousand, and 12 that have from twenty to fifty thousand inhabitants. In 1940, only 4 out of the 100 had a population of over one hundred thousand, namely, Indianapolis, Fort Wayne, Gary, and South Bend. Undoubtedly, the 1950 census will show Evansville in this group.

In the United States, it is common practice to classify cities into *small* (2,500-25,000), *medium-size* (25,000-100,000), and *large* (over 100,000). Applying this classification to Indiana cities, we have 82 small, 14 medium-sized, and only 4 large cities.

Indiana does not have a metropolis. Indianapolis, our largest city, in 1940 had a population of less than 400,000. Yet, adjacent to this state and easily accessible to our people are three cities with a million or more inhabitants. Within a radius of 150 miles of Indiana is St. Louis to the west; Chicago to the northwest; and Detroit to the northeast. Two additional large cities are located just outside the boundaries of the state. To the southeast is Cincinnati with a population of nearly a million and to the south is the large city of Louisville. Chicago, Cincinnati, and Louisville are so close that the metropolitan districts of which they are the centers, actually occupy parts of our state.

In this post-war period, the small size of our cities may be an advantage. Industry is moving from larger to smaller cities. Big enterprises are beginning to scatter their future plants rather than concentrating them in one place. The National Industrial Conference Board reported in May, 1948, that "It had queried 148 large manufacturing companies and learned that of the plants they built or acquired before 1940 nearly half were in cities of 100,000 and more. But in the period 1940-1947, only one-third of the new plants were in cities that large. Cities of from 10,000 to 100,000 were most popular. There was a large increase, too, in the number of new plants placed in cities of 10,000 or fewer." Let us keep in mind that all but four of our cities have a population of less than 100,000.

Pattern of Indiana Cities

The cities over the state are so distributed that they form several major and minor patterns. Looking at a map, one can see at first glance that they are grouped along an axis extending in a northeast-southwest direction across the state. A line drawn from Evansville on the southeast through Indianapolis to Fort Wayne on the northeast marks the approximate core of this axis. Adjacent to this line and on either side of it are grouped most of the large and small cities of Indiana.

This northeast-southwest axial pattern is due to a combination of physical and cultural factors. Some of these factors are: 1. the orientation of Indiana rivers from northeast to southwest, especially the Wabash and the west fork of the White River; 2. the early significance of water transportation, especially on the Maumee-Wabash rivers and canal; 3. the extension of the National Road from Richmond to Indianapolis and Terre Haute; 4. the Kankakee swamps in northwestern Indiana between the Wabash drainage area and Lake Michigan; and 5. the poorer agricultural potentialities in southeastern Indiana.

The one big exception to this axis pattern is a group of cities in the extreme northern part of the state. Here a second and smaller axis consists of cities grouped along a line drawn from South Chicago and Gary to South Bend and Elkhart.

Another major city pattern is the semi-circular zone of cities found grouped to the north half-way around Indianapolis. This semi-circular zone starts with Terre Haute on the west and swings north through Lafayette to Logansport and Peru. Then it turns southeastward through Marion, Muncie, Anderson, and New Castle, and ends in Richmond and Connersville. In this zone and within a seventy mile radius of Indianapolis are 15 of the 27 cities having a population of between ten and fifty thousand. Also within 70 miles of Indianapolis and to the south are three additional cities of ten to fifty thousand that form a nucleus which may someday help extend the semi-circular zone and make it a circular one. These three cities are Bloomington, Columbus, and Bedford.

The cities in southern Indiana are generally smaller than those in the central and northern parts. South of a line drawn from Terre Haute to Indianapolis and Richmond is more than a third of the state. Of the 34 cities in this southern area, 25 have less than ten thousand inhabitants. Evansville is the only large city. In this area we also have two of our 12 cities ranging from twenty to fifty thousand in size, and six of our 15 cities from ten to twenty-thousand.

There is a large wedge-shaped area in Indiana that does not have one city with a population of over ten thousand. This area is between the Wabash valley and the Chicago metropolitan district and is occupied in part by the recently drained swamplands of the Kankakee River.

A distinctive minor urban pattern is a line of cities strung along the Wabash-Maumee Rivers. Today water transportation along this historic route is insignificant, but these cities after their early start continued to grow because of other geographic factors.

In fact, most Indiana cities of ten thousand or more started as pioneer settlements on waterways and state and national highways. Later they became focal points for railroads, electric interurban lines, and hard surfaced roads.

Growth

From the standpoint of an opportunity to grow, our cities exemplify that early settlements that provided governmental services had the advantage over those that did not. Sixty-three of our 100 cities are county seats. Of the 15 cities with populations of ten-twenty thousand, only two were not county seats, namely, Elwood and Whiting. And only three out of the 12 cities with population of twenty-fifty thousand are not county seats, namely Elkhart, Michigan City, and Mishawaka.

Although the political function was and still is an important factor in the development of our small cities, the presence of urban facilities is an increasingly important factor today. Young people are more critical of their environment and perhaps better able to evaluate it. Influenced by movies, newspapers, radio and the rapidity and ease of travel, our people are observing, comparing, and evaluating various communities. Most people want homes in cities that have paved streets, water and sewage facilities, larger schools, parks, and a variety of professional services. The county seat is often able to measure up to these demands more so than other settlements.

Our urban centers also illustrate the importance of an early start. With few exceptions, the largest cities in 1900 were still the largest in 1920 and 1940.

Since 1900 and especially since 1920, manufacturing rather than retailing, wholesaling, or mining greatly influenced the growth of urban areas. Although mining and quarrying contributed materially to the growth of many cities, few today owe their present size primarily to these industries.

After 1910, the largest urban development took place in strategic northwestern Indiana. This area is astride the important lowland corridor of transit from the portal city of New York to the focal city of Chicago. In the future there will be a tendency for cities here to increase in size and number until they nearly coalesce, forming a continuous urban area from South Chicago to South Bend. The prospects of steady growth for our cities are good.

Some Geographical Factors Affecting the Industrial Expansion of Columbus, Indiana

JAMES LEE GUERNSEY, Indiana State Teachers College

Location

Columbus is located at 39° 13′ north latitude and 85° 56′ west longitude. It is about forty miles south of Indianapolis, seventy miles north of Louisville, seventy-five miles northwest of Cincinnati and two hundred forty miles east of St. Louis.

Columbus has numerous advantages of its general location. (1) It is located near the nation's center of population. (2) It is located in

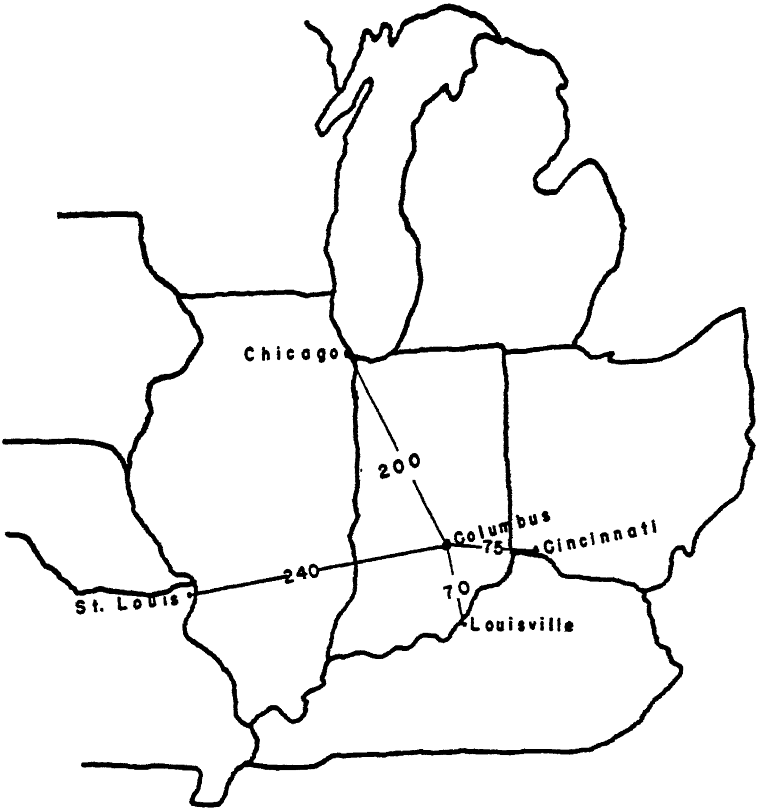


Fig. 1. Columbus—its location with respect to other midwestern cities.

Industrialization

the more progressive eastern half of the United States. (3) The city is located in one of the best corn and wheat belts of the world. (4) It is close to all the major markets of the Middle West. (5) The climatic conditions are favorable for agricultural crops, human energy, and general progressiveness of the people.

Columbus has numerous specific locational advantages for industrial concerns. (1) Proximity to Indianapolis is an advantage as it furnishes a market for various finished products. Indianapolis also supplies wholesale goods to the Columbus area at a relatively low cost. (2) Columbus is favorably located in regard to railroad and highway transportation facilities. (3) Geologically, Columbus is located on the Scottsburg Lowland. The lowland is an erosional and glaciated plain with little local relief which facilitates mechanized agricultural activities and communications. (4) It is situated on a fertile outwash plane formed by the overflowing of Flatrock and Driftwood rivers. This outwash plain is one of the most fertile areas in Indiana. (5) Its location along the East Fork of White River furnished an early means of transportation and has been a source of the city's water supply for many years.

Columbus had 87 industrial concerns in 1947. These industries are well diversified and include metal industries, furniture factories, canneries, plating companies, tanneries, meat packers, and clothing manufacturers. A few of the many various products are auto parts, building supplies, construction tools, electric fans, flour, paper, toilet articles, radios, and Diesel motors.

In 1947 there were 7,768 persons employed in industries. This is about 45 percent of the estimated population of Columbus and about 23 percent of the total population of Bartholomew County. Industrial concerns have increased from 41 in 1940 to 87 in 1947 and the Columbus Chamber of Commerce claims to have more industries per thousand population than any city in Indiana.

The total employment has increased from 3,705 in 1940 to 6,484 in 1943 and to 7,768 in 1947. In 1940, Columbus ranked second in the value of manufactured products per inhabitant in Indiana cities.[1]

The land use map of Columbus (Fig. 2) shows the distribution of the industrial concerns. About one square mile is included in these industrial zones. The industries are scattered since the city has had no city planning commission or city zonation program. The industries are usually found next to the poorer residential districts and the newer industries are usually farther from the general business area although few industries are found outside the city limits.

The payrolls of the industries have increased from $7,969,200 in 1940 to $13,794,892 in 1944 and to $16,794,892 in 1947.

Why have 87 different industries come to Columbus? Why can the Columbus Chamber of Commerce boast of more industrial concerns than any other city in Indiana per 1,000 inhabitants? There are many

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[1] Freeman, Otis. "Major Cities in Indiana." Economic Geography. 1945. p. 120.

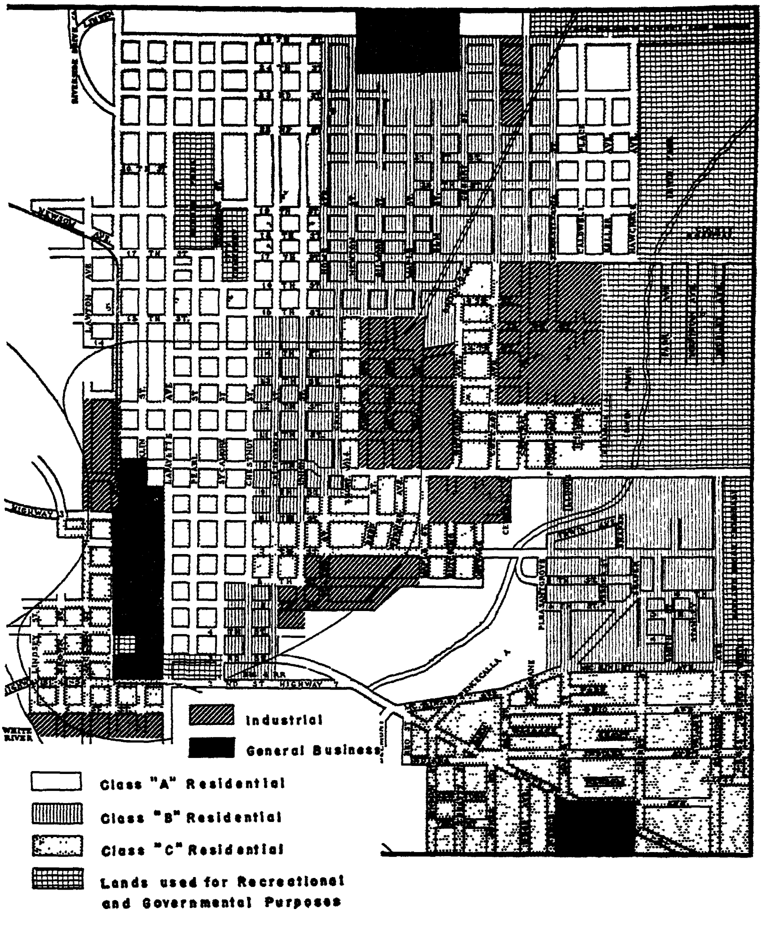

Fig. 2. City land use map of Columbus.

different reasons given by local citizens, but it is generally agreed, that Columbus has the basic conditions for a large industrial development.

Raw Materials

First, Columbus is in a favorable position to obtain raw materials. The canneries, milling companies, paper producers, lumbering mills, dairies, stockyards, chick hatcheries, and tanneries obtain a major portion of their raw materials from the surrounding agricultural area in Bartholomew and adjacent counties. The various metal industries are near the coal deposits in southwestern Indiana, and also fairly near the steel producing areas of Gary, Hammond, Youngstown, and Pittsburgh. Various engineering companies favor the position between Indianapolis, Chicago, St. Louis, Louisville, and Cincinnati from which they secure a major portion of their raw materials to be finished. The nearness to large mid-western packing centers is a favorable factor for the tanneries, and the plastics companies like the location mid-way between Tennessee and Michigan for the securing of their raw materials.[2]

Labor

Since the population of Columbus is only about 15,000 and there are 7,768 people employed in the 87 industrial concerns of Columbus, it is necessary that the industries obtain a considerable amount of their labor from the surrounding area.[3] Although the industrial workers are usually unskilled at the time of employment, most industrial employers agree that the laborers are relatively easily trained and now most industries have a sufficient supply of skilled and semi-skilled workers.

Camp Atterbury has played an important part in the recent population growth and labor supply of Columbus. Camp Atterbury is located about eight miles northwest of Columbus and occupies about 42,000 acres in Bartholomew, Brown, and Johnson counties although about four-fifths of the camp is in Bartholomew County.

Camp Atterbury added to the labor supply of the Columbus' industries primarily by three methods: (1) In the site selected for the camp were about 700 families who had to sell their farms. So about 700 families were faced with no means of earning an income; consequently many obtained employment in industry. (2) During the period of extensive operation the camp averaged about 25,000 soldiers. Many of these men lived "off post" with their families in Columbus and since the war has ended many have stayed in Columbus and have gained employment in industry. (3) Camp Atterbury employed about 14,000 carpenters, plumbers, painters, and other types of construction workers to get the camp into operation. Many stayed in Columbus after the construction work was completed and today they are a part of the industrial labor supply. So Camp Atterbury has been a part of the reason for the excellent labor supply which has been helpful in the notable industrial expansion of the city.[4]

Market Areas

Columbus is centrally located for marketing the finished products. Many of these products are sold within Bartholomew County as many industries are dependent upon local consumption as a principal market. However, most of the metal industries supply finished products to various mid-western cities. Indianapolis, Chicago, St. Louis, Cincinnati, Louisville, Cleveland, Dayton, and Detroit are all market areas for varous industries of the city. One industry has attained such marked customer diversification that it supplies every volume builder of cars and trucks with at least one item for standard equipment.

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[2] Of the returned questionnaires from industrial concerns, a favorable location for the securing of raw materials was the most frequently mentioned advantage of Columbus as a permanent location for their industrial concern.

[3] One employer estimated that about forty percent of the city's employees are from out of town.

[4] In the questionnaire returns, a good labor supply was the second most frequently mentioned advantage of Columbus as a permanent location for their industry. Only two industries listed labor as a disadvantage and each stated that there was a tight labor market in the city. Both companies paid less than the average wage for labor in the city.

Transportation

Columbus is located on United States Highway 31 which extends from the Gulf of Mexico at Mobile to the Great Lakes at Chicago;

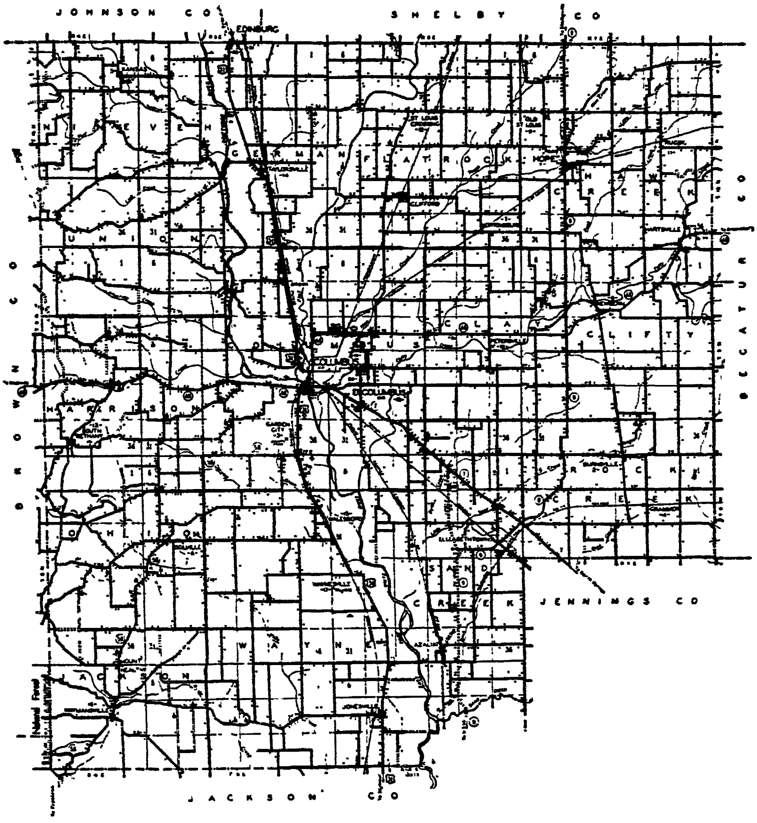

Fig. 3. General highway and Transportation map of Bartholomew county.

also, State Highways 46, 7, and 58 converge at Columbus, and State Road 9 begins near the city and extends into Michigan (see Figure 3). With these highway facilities, nine truck routes, and six bus routes pass through the city.

Today the most used method of transporting raw materials to the industries is by truck. One reason for the predominant use of trucking facilities by the local industries in the excellent highway facilities, and numerous industries own a major part of their trucking facilities. The

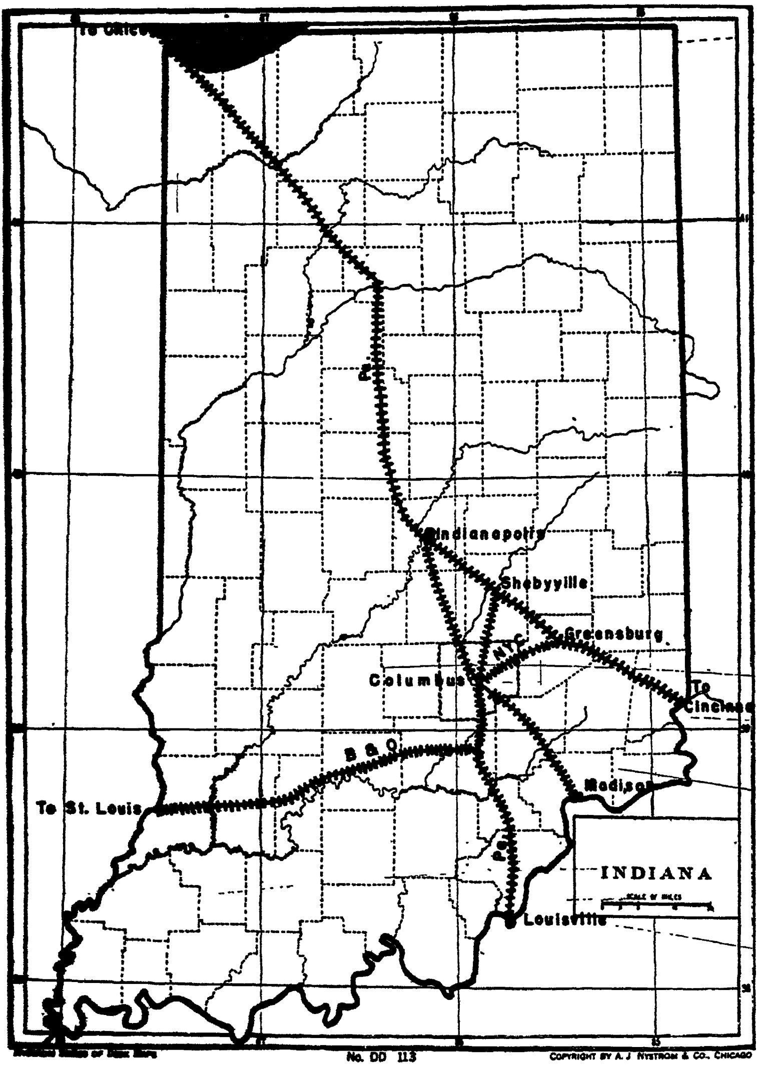

Fig. 4. Railroad pattern of the Columbus area.

good road system converging at Columbus is indicative of the desirability of its location and also of the transportation facilities required to service its needs.

Columbus is also located favorably in regard to railroads, since it lies on the main line of the Pennsylvania Railroad which runs from Chicago to Louisville and is also located on the Madison and Richmond branches of the same railroad (Figure 4). The New York Central Railroad extends from Columbus to Greensburg, where it joins the main line from Chicago to Cincinnati.

Railroads are used by the industries to almost as great a degree as the trucking facilities. Most industries consider the railroad facilities of Columbus to be good, although some complain of the high cost of transporting raw materials from the eastern part of the United States. Also, a few other concerns mentioned the fact that the rates to Columbus were not as low as they were to some other nearby but larger cities.

Tax and Utility Rates

The tax rate of Columbus in 1944 was $3.30, in 1945 and 1946 was $3.72 but increased to $5.02 in 1947. The average of other Indiana cities of similar size was $3.91 in 1944, $4.14 in 1945, and about $4.50 in 1947. The sharp increase was caused by the city's attempt to construct and repair streets, change the source of city water, install a sewage disposal plant, and repair or replace other municipal facilities. Since the tax rate was below the average for Indiana cities of similar size before 1947, tax rates were also a definite locational advantage.

The city's utility rates are about the average for Indiana cities, and industrial concerns no longer consider them an advantage, as they were for several years; although since they are about average they are not a serious disadvantage.

City Benefits

One of the most striking evidences of the thriving economy of the city is the large class "A" residential districts (see figure 2). The newer, more expensive houses are located in the northern portion of the city, and are largely homes of industrial officials. However, the unusually large portion of the city in class "A" homes is not the only benefit derived from the recent industrial expansion. Other benefits are: (1) Employment for the people of the city and surrounding area. (2) Increased buying power for the city and its population. (3) City improvements made possible. (4) Industrial diversification, and (5) decreased individual tax load.

The Electric Light and Power Industry of Indiana

R. K. CASSELL, Indiana University

The State of Indiana is one of the ranking producers of electrical energy and its companies operate in parallel with an interconnected system of twenty-five power producers which supply Northern Kentucky, Indiana, Southwestern Michigan, Ohio, Western Pennsylvania and West Virginia. About thirty percent of the United States total weekly power output is generated in these states. Nationwise the State of New York, with generating capacity of 5,500,000 K.W. leads the major producers, with Indiana standing seventh with 1,700,000 K.W. at the end of 1947.

Before the turn of the century it could fairly be said that there was no electric light and power industry in Indiana. To be sure electrical energy was produced but not as a commodity for sale. A few factories generated electricity to power machines which might be used in the manufacture of household goods or farm implements; the South Bend railroad powered a street railway with electricity; and some cities had installed electric lighting systems. But not until after 1900, when the problems of distribution of energy had been solved, did the industry develop in Indiana.

Until World War I Indiana was far behind the surrounding states in production of electrical energy but by 1920 she had increased generating capacity to within a third of that of her most important neighbors. From 1920 to 1940, despite eight depression years, generation capacity more than doubled. Although, still a third behind these most favored neighbors in electrical generation capabilities in 1940, the available consumer supply of electric energy in Indiana was far above that of any of the adjoining states. In fact, it was said by some that the electric light and power industry in Indiana was over built.

It was this adjudged fact which led the Office of War Utilities and the Office of War Production to place such a quantity of war production contracts within the state that Indiana had the singular distinction of having the highest per capita war production in our Union from 1942 through 1945.

At the war's end, general industrial production slumped while generating capacity stood by. But the duration of production decline was not for long—not long enough for the electric light and power industry to replace old worn out equipment, or for making necessary repairs in the midst of a situation where metals and parts used in the electric industry were in very short supply.

During the first quarter of 1946 the demand for electricity increased to such an extent that the industry was called upon to supply more electrical energy than was safely available. Because electrical energy cannot be stored, generating plants must be large enough to supply power in amounts equal to peak load requirements. Furthermore, in order to guarantee a firm supply, and to be able to meet emergency situations, it is producer policy to provide a plant with 15 percent more generating capacity than is required of it during the peak load intervals. It is this margin of reserve between load and capacity[1] which has helped to supply the increased demand and many times this margin has been dangerously small. Hence, from time to time warnings are sent out about power shortage, and the larger consumers are asked to shift intervals of maximum consumption to off-peak hours.

Plants now under construction and new plans in progress warrant a substantial future increase in generation capacity. It is quietly accurately estimated that the amount of available energy in Indiana by 1950 will be double that of 1940.

Characteristics of the Industry

The industry is composed principally of six operating companies, namely Public Service Company of Indiana, Southern Indiana Gas and Electric Company, Indianapolis Power and Light Company, Indiana Service Corporation, Northern Indiana Public Service Company, and Indiana and Michigan Electric Company.

The sites of power generation are concentrated either in areas of maximum consumption or at points of low cost of production. While the map (figure 1.) shows that there are wide areas without generating capacity, it also indicates the transmission system over which power is distributed throughout the state. The trend of bringing power to the worker has been so strong in Indiana that it has been one of the leading states in bringing about the industrial revival of the countryside.

Besides the intricate transmission and distribution system of the several commercial companies is the potent factor of integration. There is a complete system of interstate as well as intrastate inter-connection. Such tie ups permit a company, for instance, to purchase power needed at peak load intervals, and at other times to dispose of surplus power, and provides mutual aid for all companies in times of emergency.

There are 84 municipal plants in the state with only one generating as much as 25,000 KW. Fifty-four of them buy all their power from the commercial producers. Among the larger municipal plants such as Anderson, Richmond, Crawfordsville, Logansport and Goshen, to mention the most representative cities (figure 1.), power is drawn from the utilities' transmission system, either to reinforce firm supply or for standby emergency use. The twenty odd smaller municipal plants have

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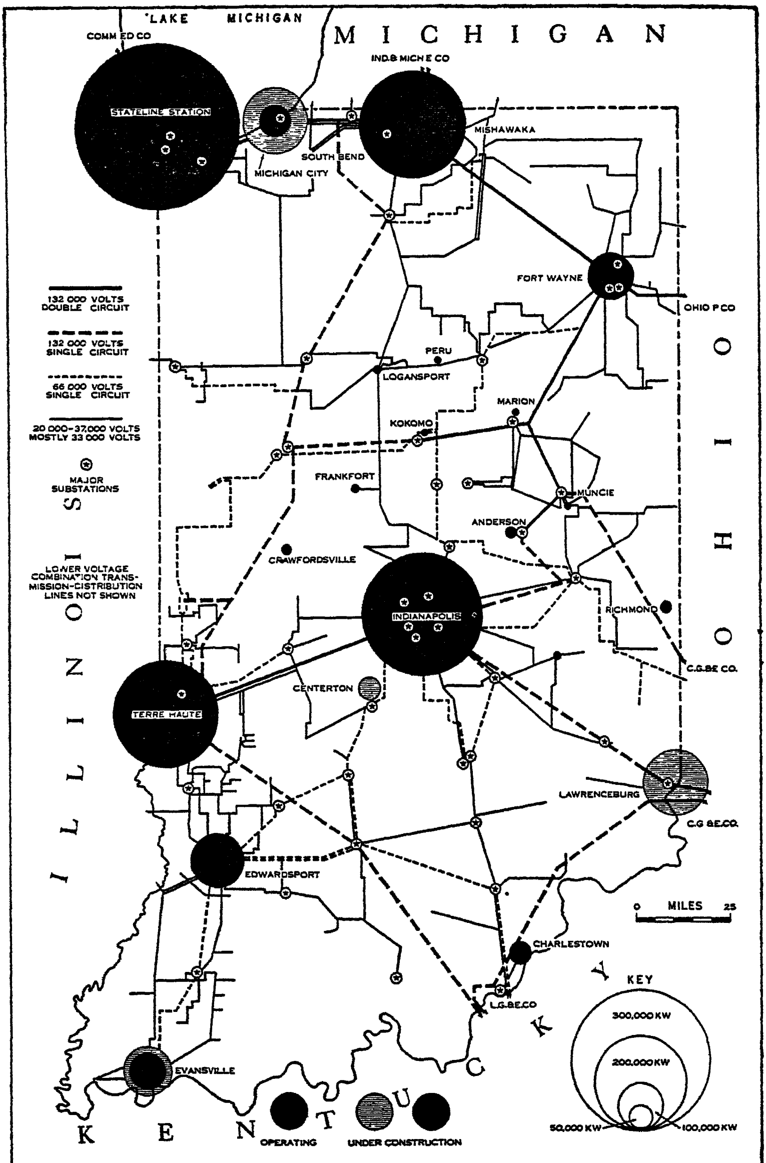
[1] Data on generating capacity is almost always shown in terms of manufacturers' "name plate rating"—the capacity which the manufacturer will guarantee. Usually, due to differences in operating conditions, or to modification after installation, the actual capacity is quite different, mostly higher than the nameplace rating. This unrecorded capacity plus the fact that most generators are capable of carrying considerable overload for a period of time have more than once prevented derangement of service during the period of short supply.



GENERATING CAPACITY AND ELECTRIC TRANSMISSION SYSTEM IN INDIANA

capacities mostly under 10,000 KW., and the sum of generating capacity of all the municipal installations is only about 175,000 KW.

The consumers of electricity in Indiana, statistically divided into residential and rural, small-commercial, large industrial, and traction companies, embrace or include the greater proportion of human activity. Large industry consumes almost sixty-five percent of total kilowatthour produced with small commercial and residential and rural using around fifteen percent each, and traction companies consuming about five percent. While only eighty-five percent of our farms have been electrified, further development in this field is toward installation of larger transmission systems as farms become greater power users, rather than electrifying farms without service. Today the farms that do not have electricity are largely of the sub-marginal, self-sufficiency type and, therefore, would be little benefited by such service.

Cost of Electricity

To the consumer the cost of electrical energy, for the state as a whole, does not exceed the average of that of any neighboring state. According to the most recent series of index numbers published by the U. S. Bureau of Labor Statistics, in which the average of the five years, 1935-39, is used as the base, the cost of residential electricity stood at 89.0 in December 1947, compared with a Cost of Living, on the same base, of 167. While sales of electricity throughout the decade have increased tremendously with the resultant decline in average price of Kwhr sold, the rapid postwar increase in the trade's basic costs, plus the burdensome financing of expansion projects, will inevitably force consumer prices upward.

Most electric generators in the state are powered by steam, with coal as the principal fuel. Abundant and cheap coal has favored this type of prime mover of the generator. Moreover, Indiana's topgraphy and river regimen are such that the cost of construction of sizeable hydro-electric plants would be comparatively much more expensive. Consequently, almost ninety-two percent of the electrical energy produced today comes from the steam driven generator.

Conclusion

The electric light and power industry after a late and slow start has grown to proportions which has attracted many heavy power consuming industries with the result that a power shortage became a serious threat. But now programs are under way to establish the normal reserve of plant and equipment and promote general growth of the industry. Supplied mostly by large operating companies, no urban and practically no rural population unit in Indiana is now without service.

Hudelson Cavern, A Stormwater Route of Underground Lost River, Orange County, Indiana

CLYDE A. MALOTT, Indiana University

Drainage Characteristics of Indiana Caverns

The limestone caverns of Indiana are features of subterranean drainage, though many of them are now above drainage level and are dry. The relationship of many of the dry caverns to their former sources of water supply is relatively obscure, chiefly because only remnants of their courses are available for study and too little is known about their actual linear ramifications. Numerous caverns in the limestone region of southwestern Indiana, however, are still the routes of subsurface drainage, though only a few of them may be explored through much of their courses. Many of the stream-coursed caverns have definite relations to their sources of water supply, while some have rather obscure relations. Most of the stream-coursed caverns get some of their waters from seepage through the general overlying and contiguous bedrock which slowly feeds clear waters into them, mainly through joint controlled routes. Such a supply of waters to the cavern streams is relatively continuous and uniform. These caverns are usually developed close to drainage level and their courses, except in a few cases, may not be followed far. But many of the stream-coursed caverns of the limestone belt receive surface waters from definite places of intake, and their stream volumes are subject to rainfall and drainage variations. These caverns in addition to their flows of clear groundwater, are subject to the excess waters of rainy periods, and the stormwaters fed into them from the surface may be charged with muds, silts, sands and gravels. Such caverns may be entered only during dry periods when their water flow is relatively small. Some of the stream-coursed caverns carry only stormwaters and have intermittent flows of water. Such caverns occasionally have higher levels which are subject only to the influx of storm-born waters which over-tax the lower routes, and occasionally they may have dry sections completely above the inflooding storm-born waters.

Nearly all of the better known caverns of southern Indiana are stream-coursed with the exception of Marengo and Wyandotte caverns, and most of them carry storm-born waters entering at definite places of intake. As such they are the routes of underground drainage. Many caverns are completely sealed and carry both ground and storm waters. Their terminal ends are the sites of large springs which are at or slightly below drainage level and cannot be entered. Many caverns, however, terminate above drainage level and open widely at their lower ends. Porter's, Boone's, Ray's, May's, Donnehue's, Hamer's, Donaldson's, and the Clifty caverns are examples which discharge their waters through relatively large openings that in large part are above drainage level. Only a few caverns in southern Indiana may be entered at their upper ends where they receive their surface waters. The American Bottoms caverns of eastern Greene County and Eller's and Saltpetre caverns of western Monroe County are examples. In many cases entrances to caverns are through sinkholes which may open directly or indirectly into the cavernous routes. Entrances to the underground Lost River at Wesley Chapel gulf, the Tolliver gulf, and Hudelson cavern are examples. Trinkle cavern, near Hardinsburg, Washington County, is a collapse sinkhole entrance to Sinking Creek, Marengo cavern was originally entered through a sinkhole. The Donaldson cavern system of the Spring Mill State Park may also be entered at two different places where sinkhole breakdowns have occurred.

Stream-coursed caverns, especially those which carry gathered stormwaters from the surface, offer little attraction as scenic features and are seldom visited by the public. Only a few of them have been described in detail, and still scantier attention has been given to them as subterranean drainage routes. It is the purpose of this paper to present some of the details of a stormwater course of underground Lost River, locally known as the Hudelson cavern. This cavern was entered and mapped by the writer and Robert Shrock in August, 1929, during a study of the Lost River region of Orange County. Few people know about the presence of the cavern and only a small number have been in it. It is an unattractive, muddy cavern, and in addition may be considered dangerous.

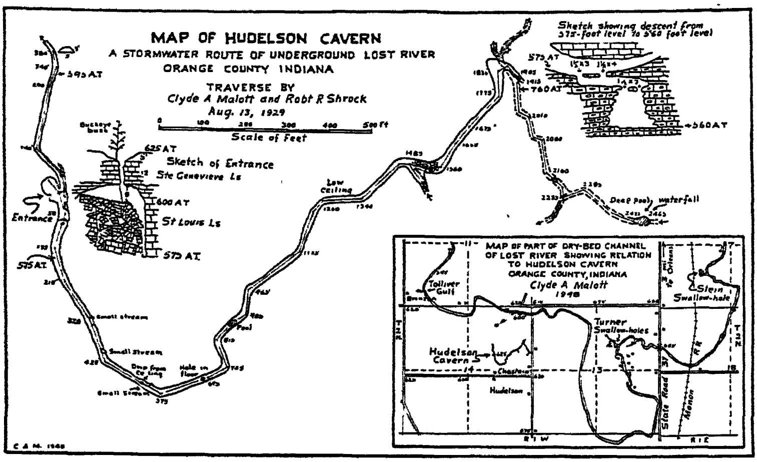
Lost River Drainage

Lost River, carrying waters from 53 square miles of drainage, sinks in various small and several large swallow-holes along its middle course. Its first sink is a small one in the SW ¼ of sec. 4, T. 2 N., R. 1 E., about two miles southeast of Orleans. This sink carries all of the water fed into it during rather dry periods and marks the very beginning of the dry-bed channel. During much of the year, however, Lost River sinks in several rather well defined but shallow swallow-holes west of the center of sec. 8, about one mile farther down stream. If rains overtax the capacity of these swallow-holes, the excess waters enter various swallow-holes farther down stream. The Stein swallow-hole in the SW¼ of sec. 7 has a large capacity, but heavy rains send stormwaters beneath the bridge on State Road 37, about three and one-half miles south of Orleans, and on to the Turner swallowholes in the NE¼ of sec. 13, T. 2 N., R. 1 W. Still heavier or continued rains send the waters throughout the winding course of the dry-bed channel which is more than 20 miles in length. The rise of the underground stream is on the Allen farm, near the center of sec. 7, T. 2 N., R. 1 W., about three-fourths of a mile south of the village of Orangeville. The direct distance between the first swallow-hole and the rise is about 8 miles, but the underground course is undoubtedly much longer.

Very little is known about the underground course of Lost River. It is probably not a simple underground course, but is characterized by many channels developed along routes hewed out from the joint system in the upper part of the St. Louis limestone in which it is developed. This complex system is well illustrated in the explored routes of the underground system at Wesley Chapel gulf where it has been partially mapped and described by the writer in a special paper written in 1931. The underground routes in the region of the first sinks are but little below the surface channel, but descend to as much as 30 feet below the dry-bed at the Turner swallow-holes. They are as much as 40 feet below the dry-bed at the Hudelson cavern and at Tolliver swallow-hole to the west. In approaching the rise of the underground stream, the dry-bed is cut deeply below the general sinkhole plain and the underground channel or channels are only slightly below the dry-bed. During flood periods, however, the system occupies levels much above the low water routes, coursing through levels as high as the dry-bed itself. The underground system has both low and high water levels. At the Hudelson cavern and the Wesley Chapel gulf these have a vertical range of 40 feet or more.

Name and Location of Hudelson Cavern

The Hudelson cavern takes its name from a former owner of the farm on which the sinkhole entrance is located. The land is now owned by Austin Chastain. The entrance is in the east part of the SW of the NE¼ of sec. 14, T. 2 N., R. 1 W., about midway between Orleans and Paoli and about one and one-half miles west of the bridge across the dry-bed channel on State Road 37. It is 360 yards north of the Chastain residence and 550 yards south of the dry-bed channel of Lost River. See inset map of figure 1. The Hudelson cavern is in the midst of the sinkhole plain through which the dry-bed channel of Lost River passes. Entrance to the cavern is attained through a small sinkhole at an altitude of about 625 feet, some 25 feet above the level of the dry-bed of Lost River. The relief of the sinkhole plain is relatively small



though in about one mile to the south the edge of the rugged Chester escarpment rises as much as 200 feet above the sinkhole plain, exceeding 800 feet in altitude. The cavern itself is developed at three levels beneath the sinkhole plain. The cavern floor immediately beneath the entrance is about 25 feet down. A small high-level channel extends northward at an altitude of about 595 feet. The middle floor is at an altitude of 575 feet. The lowest floor, at or near the permanent watertable, is at 560 feet in altitude and lies 60 to 100 feet beneath the undulating sinkhole plain. All the floors of the cavern are developed in the St. Louis limestone, though the uppermost floor is near the contact with the Ste. Genevieve limestone which composes the surface lands of this part of the sinkhole plain.

Description of Hudelson Cavern

The sinkhole entrance to the Hudelson cavern is a small one. It is about 15 feet across and depressed only about 5 feet below its rim. It is marked by a buckeye bush which grows at the edge of the open hole in the bottom of the sinkhole. The opening in the sinkhole is about 2½ feet across. It extends vertically downward through 12 feet of rock to the ceiling of an expansive room 8 feet above a rather flat floor. The room is approximately 40 feet across in an east-west direction. It extends northwest 45 feet where the ceiling descends to the floor. The land floor of the room is composed of blocks of mud-covered rock, indicating that the muddy stormwaters of underground Lost River cover the floor. They do not reach to all parts of the ceiling of the room. Southward the floor descends slightly and in about 75 feet descends abruptly into muddy pits into which stormwaters from the south disappear during high-water periods. This east wall of the room is composed of thick bedded layers of rock, and the floor, composed of mud-covered fallen blocks of rock, abuts closely. The wall, however, descends about 25 feet to the 575-foot level of the cavern. Northward, a rather small passage was followed for about 400 feet at an altitude of 595 feet. It is a high-level escape route of stormwaters at or near the level of the dry-bed channel of Lost River. It's floor and ceiling are rather irregular and in places the passage itself is rather constricted. Everywhere the route indicates the northward passage of muddy stormwaters. At 380 feet from the entrance the passage was only 3 feet high and 5 feet wide and was not followed farther.

Southward 75 to 100 feet from the entrance the 575 foot level of the cavern is reached. A stream channel with a mud wall on one side and the massive rock of the cavern on the other side terminates in muddy pits and against the blocks of rock composing the platform of the entrance room. This channel is continuous with the 575-foot level throughout with few interruptions. The stormwaters when present apparently enter the pits and in part go around the east wall of the entrance room and thence northward down the high-level passage. The 575-foot level extends south-southeast for a distance of 575 feet, where it turns northeastward. See traverse map, figure 1. A little water trickles along on the narrow floor of the mud channel. This channel is 5 to 10 feet in depth and the cavern ceiling is 5 to 15 feet above its floor. The cavern itself is 12 to 25 feet in width. A small trickle of water enters from the east (left side) at 320 feet from the entrance, and another at about 400 feet, and still another at about 540 feet. Water drips noisily from a hole in the roof at 525 feet and a shallow plunge pool is present in the mud floor here.

After turning northeastward the narrow bottom of the mud channel is directed into a small hole in the floor at a distance of 675 feet from the cavern entrance. The northeastward stretch of the mud-floored channel shows little change. It turns slightly here and there and the mud wall is first on one side of the cavern and then on the other. The cavern ceiling is slightly uneven in an undulating manner, but is not rough. It is usually 6 to 9 feet above the mud floor of the channel The cavern sides are 12 to 20 feet apart, averging about 15 feet. The rock everywhere is covered with mud. The mud surface is minutely uneven, and locally resembles berries. An occasional stalactite is present here and there, also well covered with mud. Nowhere does rock show on the floor of the cavern.

At 1,270 feet from the entrance the cavern is so filled with mud that it is necessary to crawl for a distance of about 120 feet. Here the roof is 2 to 3 feet above the shallow mud channel of the floor. At 1,485 feet from the entrance the mud channel becomes double, one channel coming from the left (nearly due east) and the other coming from the right (southeast). The cavern widens into a room about 60 feet across. The channel on the right comes out of broken-down rock next to the right wall of the cavern. It did not appear big enough to enter, and no attempt was made to follow it. The channel on the left comes through broken-down rock, and a ridge of mud rises sharply between the two channels. The left channel was followed by going over mud-coated rock slabs adjacent to its right wall, and in about 75 feet the mud channel was again entered.

The mud channel continues northeasterly to a large room 1,835 feet from the entrance to the cavern. The ceiling of the room is 15 to 20 feet above the floor, and on the northwest the mud floor rises to the ceiling in a distance of about 40 feet. It seems probable that the main cavern once extended in that direction, but has been completely sealed off by accumulated muddy silts. A hole above allows water to fall into the room, and a ditch-like channel leads from the plunge basin southeasterly under the rock ceiling to a lower level. Apparently surface waters enter here during rains. At the southeast end of the big room, close under the ceiling, ragged holes in the rock floor lead to the low-level route of the cavern developed at an altitude of about 560 feet. These holes are 1,905 feet from the entrance of the cavern. It is quite apparent that stormwaters fill the lower route to its full capacity and then rise through the holes and flood the next level above.

The 560-foot level is at or near the permanent watertable of the region. It extends in a northwest-southeast direction. It is developed in a very cherty phase of the St. Louis limestone and presents a rough and ragged appearance as a cavern channel. Rough cherty masses extend from the walls and ceilings, and the floor is partly covered with loose chert masses. Excavated holes in the floor add to the unevenness. The storm waters appear to pass through the cavern with great force in a northwest direction. The rugged route is 6 to 10 feet in height and 10 to 15 feet in width, with occasional wider places. A mud coating is present on the walls and ceiling, but the floor is relatively free from mud.

After descending through the ragged holes to the lower level, the passage was mapped northwest in a downstream direction. At a distance of 70 feet, a pool of clear water was encountered measuring 5 feet or more in depth with a ceiling only 2½ to 3 feet above the water. The passage turns slightly to the right and could be observed for only 30-40 feet beyond the end of the traverse. Upstream from the entrance holes the low-level cavern route was mapped for a distance of 550 feet from the entrance holes and 2,425 feet from the entrance to the cavern, where the traverse was stopped by a pool of water occupying a plunge basin beneath a waterfall ledge 3 feet above water level. A blind fish fully 5 inches in length was observed in the clear water of the pool. At 320 feet from the entrance holes, a lead goes off to the right (south-southwest). It is smaller than the main channel and is nearly filled with loose rock. Apparently stormwaters from the main channel feed into it. Ripple marks and etched rock clearly indicate water passage into it. It's floor 75 feet back from the main channel is considerably higher than that of the main channel. It is possible that the waters which follow this lead are fed into the 575-foot level in the room 1,485 feet from the sinkhole entrance to the cavern system.

Stormwater Drainage in Hudelson Cavern

The Hudelson cavern was entered and explored in the hope that it would lead to the low-water route of the main channel of underground Lost River. It seems quite probable that the explored part of the cavern is south of the main route. The 560-foot level, however, very probably leads directly into it. Swallow-holes in the dry-bed just to the north of the cavern are directed southward from the dry-bed, evidently leading into the underground route of Lost River somewhere between the mapped part of the cavern and the dry-bed channel. The cavern was again entered during a dry period in June, 1931, and a further attempt was made to trace the low-level route to the main course of underground Lost River. The route was extended for 100 feet or more by wading through water varying from knee to waist deep, avoiding the deeper places. Numerous white blind crawfish were noted and two blind fish up to four inches in length were observed in the clear water. The walls of the cavern are very rugged with chert masses, and the ceiling is irregular in height, varying from a few inches up to 10 feet above the water. At the end of the traverse the ceiling came down to within a few inches of the water, but beyond it could be seen to rise again over rather deep water. The total traverse of the cavern system aggregated 3,200 feet.

The stormwaters which course through the triple-floored Hudleson cavern rise as high as 605 feet in altitude, as much as 45 feet above the low-water route at or near the watertable of the region. There are two possible sources of these stormwaters. It is possible for them to come from the surface streams which descend from the Chester escarpment south and southeast of the cavern, where several ravines send their rain-born waters into individual swallow-holes on reaching the sinkhole plain. These waters undoubtedly reach into the underground system of Lost River, though their actual routes are unknown. The second possible source of the muddy stormwaters is from the dry-bed channel of Lost River entering through the numerous Turner swallow-holes near the center of the NE¼ of sec. 13, about one mile east of the cavern entrance. See in-set map, figure 1. It appears quite probable that this is their source. The traverse of the cavern system ended at the up-stream end 1,400 feet nearly due east of the cavern entrance and directly toward the area of the dry-bed swallow-holes. It is regrettable that the traverse was not continued in this direction in spite of the deep pool of water which discouraged further exploration. This source is highly adequate, and the behavior of the waters flowing through the cavern system seems to indicate such a source.

It is apparent that the stormwaters course through the cavern with considerable velocity during an early period of flow, but later the waters become stagnated or flow very slowly. The high velocity period is associated with a filling period when large quantities of water enter the Turner swallow-holes from the dry-bed. Later, the underground routes become filled with stormwaters and the velocity of flow is checked, chiefly because of the stormwaters entering the lower part of the system down-stream. These waters in their use of the down-stream part of the underground system partially block the waters in the up-stream part. Decreased volumes then enter through the swallow-holes in the upper part of the system, and the excess stormwaters descend down the dry-bed channel. The stagnated muddy waters deposit muds in the underground routes of the system, especially in the higher levels, such as the 575-foot level of the Hudelson cavern. The walls and ceilings become heavily coated with mud and dead-end channels become filled. These waters stand as high in the system as the flood waters in the dry-bed channel and they cannot be evacuated until the dry-bed is lowered or emptied. Following the cessation of flow in the dry-bed, the stormwaters in the subterranean system subside and eventually cease to flow. Only clear waters seeping into the system from groundwater sources then flow through the lowest routes, except for the constant passage of waters from the upper part of the system which is spring-fed.

Conclusion

It appears quite likely that the compound vertical components of a system like that of Hudelson cavern are a result of the development of successive levels as the watertable is lowered, and that the older and higher levels are maintained and further developed by the inflooding waters from the surface. The upper levels are maintained as long as the underground tubes are not too much clogged by breakdowns in them, or as long as they are occupied by stormwaters passing through them. Later stages in their history are associated with incoming flood waters which do not flow freely because of occasional breakdowns in the passages which clog them. These stages are associated with accumulations of clays and silts brought in by the muddy waters which may fill the dead-end passages and largely eliminate them. Such clays are highly characteristic of dry caverns now above the reach of inflooding stormwaters and high above the watertable. New levels are initiated at or near the watertable by the normal phreatic waters along the permissive bedding planes and the joint system of the limestone. As such the initiated water passages are small and of little significance. When taken over by the high-pressure flood waters from the surface, they become enlarged and the selected routes of subterranean drainage are established from those more favorably located or which have more quickly become etched out and become subject to the inflooding of stormwaters gathered from surface areas. The caverns into which they develop are the result of subterranean drainage, not so much by the phreatic waters, but by the stormwaters directed into and through them.

Structural Trends of the Southern Flanks of the Wisconsin Arch

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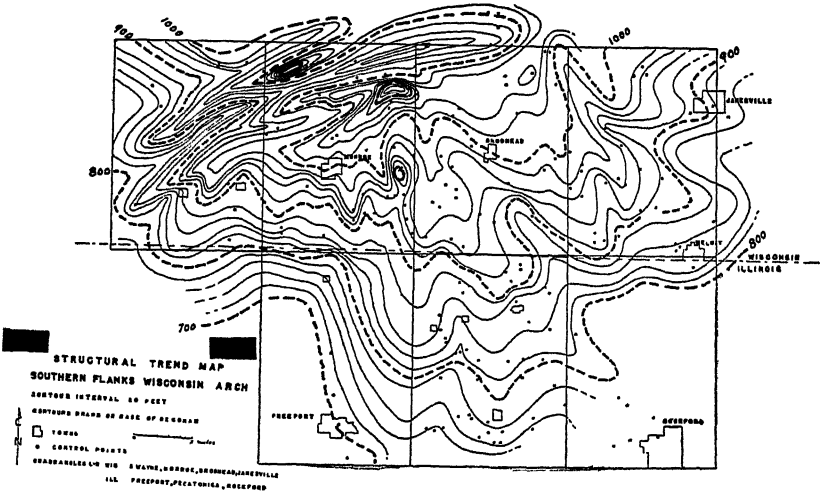
Areal geological maps of southern Wisconsin show the generalized broad pattern of the uplift in central and southern Wisconsin. The irregular areal map pattern in southern Wisconsin results mainly from erosion by streams in an area of near horizontal strata. Secondary cross structures are indicated when trend maps are drawn on a definite horizon.

The horizon chosen for mapping in the present paper is the base of the Decorah formation. Structural maps are drawn on the top of the Dresbach (1), top of the St. Peter (2), and for a small area in the Monroe Quadrangle on the top of the Platteville (3). The Decorah formation is here used for mapping because the shaly facies is generally present, the formation is near the surface in the area covered, and fossils of the upper Platteville and the lower Decorah can usually be recognized. Locally Decorah lithology simulates that of the Platteville formation below, and the Galena formation above. Elevations of Platteville-Decorah contacts are estimated from contour maps. Where formation contacts are few, covered, or not recognized, known horizons in the Platteville or Galena formations are plotted, and the proper number of feet added or deducted as the case may be. A fucoidal zone in the upper Platteville is helpful as a marker, as is a dwarfed form of *Receptaculites* in the upper Decorah.



The thickness of the formations is nearly constant. Eastward the Platteville thickens slightly, the Decorah remains at about twenty-five feet thick, while the Galena thins somewhat.

Alden's areal map (4) is used as a check, and in several instances, to mark elevations of contacts where outcrops are hidden beneath the drift.

The map shows broad anticlines and synclines gently pitching away from the main axial trace. Along the northern border of the area a sharp break in the contour lines exhibits cross structure trending southwest-northeast. Probable sharp flexures or faulting is indicated. North of the area several faults are mapped (5), striking in a like direction.

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Indiana's Geographic Regions

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Those who know Indiana recognize that it has sufficient regional contrasts to justify subdivision into at least a few regions. There is disagreement, however, as to how many merit distinctive names and as to boundaries. The present writer has made numerous maps which reveal contrasts in Indiana in respect to various environmental conditions and of responses partly there to. ("Climate of Indiana," 1944 has more than 300 maps: and more than two hundred additional original maps of other aspects of the state are presented elsewhere.) A detailed discussion of regionalization in Indiana appears elsewhere. (Annals of the Association of American Geographers.)

A study of the regions of Indiana has been made on the basis of numerous criteria, including geologic stratigraphy, glaciation, physiography, average elevations, local topographic relief, average amount of ruggedness, amount of soil erosion, types of soil, climatic contrasts, native vegetation, agricultural land use, average population density, urbanization and population changes. Maps are given elsewhere showing the regions which are discernable on these bases. Here, however, the major regions only are briefly described.

The three regions which are generally recognized are Northern, Central and Southern Indiana. These are based on a combination of differences in topography, soil, climate, land use, and historical development. Nearly three-fifths of the state is known as Central Indiana. It is generally a gently undulating glacial till plain, with poorly developed natural drainage and with numerous but mostly inconspicuous remnants of former glacial lakes. Its elevation is fairly close to 800 feet, on average about 650 at the west and about 900 at the east. The local relief is generally less than 100 feet. It's soil is largely a clay loam, and the sub-soil is scores of feet thick nearly everywhere. Central Indiana is part of the Corn Belt, one of the choice farming regions of the world. Much of it has been classed by the U. S. Department of Agriculture as Grade 1 farm land. Indiana possesses more acres of such very choice land than 30 other states combined. It comprises some of the best of the Corn Belt, with many thousands of officially recorded corn yields of more than 100 bushels per acre, and with a heavy production of tomatoes, and soybeans, and with numerous economically successful farms, many of them as small as 80 acres.

The northern one sixth of the state differs from Central Indiana partly in being less generally level, in having poorer natural drainage, in still possessing numerous glacial lakes and in having much more sandy soil. It also has numerous small areas of muck. It has less excellent farm land, on the average, partly due to the climate. Repeatedly in Northern Indiana, the frost-free season is not quite long enough for corn to thrive as well as it does in Central Indiana. The Corn Belt's northern margin is in Northern Indiana. Cold spells are more numerous and colder than in Central Indiana; snowfall normally is heavier. Northern Indiana was glaciated recently, by the Late Wisconsin Ice Sheet, and the glaciers left more conspicuous moraines, more lakes, more glacial boulders, and much more wide-spread deposits of sand than in Central Indiana. Northern Indiana was the last of the three great regions of the state to be extensively populated and it has grown most rapidly in population in the last forty years. Northern Indiana surpassed Southern Indiana in manufacturing about 1900, and recently has surpassed Central Indiana, despite the importance of Indianapolis, which contains about as many people as the three chief northern cities combined. Dairying is extensive in Northern Indiana, and the growing of truck crops, especially potatoes and onions.

Southern Indiana, approximately the southern fifth of the state, contains most of the state's hilly land, although parts of Northern Indiana are moderately hilly, as are small parts of Central Indiana. About half of Southern Indiana was not glaciated and the remainder was glaciated mostly relatively long ago (by the Illinoian Ice Sheet). The contrast in elevation is locally the greatest in the state (400 to 600 feet for a few counties). The soils of Southern Indiana average poorer than in Northern and especially poorer than in Central Indiana. Soil erosion has been notably greater, partly because of the greater average slope, the thinner soil, and the longer period of settlement. (Southern Indiana was the first region settled.) Significant also are certain regional climatic contrasts. Southern Indiana has more precipitation, especially in the cooler months, it has more torrential rainfall, much more in winter; it also has less snowfall and frost protection of the soil. Most of the people of Southern Indiana are supported by agriculture, though manufacturing is extensive in Evansville and, considerable, in proportion to their population, in several smaller cities. Coal mining is significant in several western counties. Nearly half of Southern Indiana is woodland or prospective woodland. Most of the counties of Southern Indiana have fewer people now than they had in 1890; several have declined in population since about 1870. This decline has been due partly to the general depletion of lumber, and also of top-soil. Very significant however, have been the improved opportunities available in Central and Northern Indiana and elsewhere, and the desire for more income than could be obtained from most of the farms of Southern Indiana. Of not least importance in causing the decrease in population has been a general reduction in the size of the average family.

Despite the fact that the cores of each region differ significantly, no distinct line of demarkation is observed when crossing from one region to the next. Hence the boundaries are drawn in different places, depending on what criteria are deemed of special importance. The most important basis for these regions has often been considered to be glacial. Northern Indiana was most recently and most strikingly glaciated, Central Indiana was notably affected by an earlier ice sheet, but most of the glacial effects are less obvious. The core of Southern

Indiana was not glaciated, and the rest was glaciated relatively long ago, with most of the effects not inconspicuous.

Subdivisions of Northern, Central and Southern Indiana

Each of Indiana's three major regions can advantageously be subdivided. Northern Indiana is distinctly different at the west than at the east. In the west, sand is widespread, and there are numerous sand dunes, including the fine ones along the shore of Lake Michigan and several rows of lesser ones along the former shores of the ancient enlargement known as Glacial Lake Chicago. In the east, by contrast, there is almost no sand, but instead relatively high morainic hills and deep hollows, with numerous lakes. Marshland is extensive at the west, including the Calumet and Kankakee marshes, but lakes are few. Western Northern Indiana differs climatically from eastern partly in having dryer winters, more drouths and more frequent sub-zero temperatures. The middle part of Northern Indiana, the area just east and southeast of the end of Lake Michigan, receives notably more snowfall than the rest of the state. The Northwestern corner of Indiana also differs from the northeastern industrially, as it is an eastern extension of Chicago, while little manufacturing is done north of Fort Wayne or east of Elkhart.

In Central Indiana, the contrasts between the eastern and western parts are less than in Northern Indiana, as much of the region generally is almost level, with relatively little soil contrast, except that part of the west has black prairie soil. However, partly due to differences in elevation, there are perceptable climatic contrasts. As the eastern third of central Indiana averages nearly 300 feet higher than the western third, the nights are appreciably cooler, especially during the warmer months, there is a shorter growing season, the clouds hang lower in winter, and the snow-cover remains longer. Eastern Indiana also receives more precipitation in winter, has less frequent drouths and fewer intense thunderstorms. In the development of the state, the discovery of extensive gas and oil in the eastern part of Central Indiana in the late 1880's, and 1890's, but only locally elsewhere, was significant. It led to the rapid growth of several towns in the "gas belt" into manufacturing cities. Conversely, coal is extensive in much of the western counties of Central Indiana but not elsewhere in the state, except in western Southern Indiana. Coal has been a significant influence in the development of the areas where it has been extensively mined.

In Southern Indiana, there are notable contrasts. The western fourth, approximately, is the Wabash Lowland, with extensive, fairly level tracts and the lowest average elevation in the state (much of it 400 to 500 feet above sea level). The growing season is the state's longest, the night temperatures highest, snowfall least, rainfall heaviest, and there is most winter sunshine. That section is also mostly underlain with coal, and numerous scattered small areas have yielded oil or gas or both. Most of the Wabash Lowland is good farming land where corn growing is extensive and melons locally important. The soil is partly loessial, partly lacustrian and extensively alluvial.

To the east of the Wabash Lowland is a broad zone of steep hills developed on sandstone, with generally poor soil. It has few people and much wasteland. Next east is a "limestone valley" averaging about 15 miles wide, notably less rugged than the zone just mentioned but by no means flat. It contains myriads of limestone sinkholes and some sharp hills; indeed some of it has a mild "karst topography." There are numerous caverns, one glamorized as "Lost River." Its soil and topography are, however, better than in areas adjacent to the east and west. The Monon Railway follows this "Valley," which contains several small cities, including Bloomington, Bedford, Paoli and Salem. This is the "Indiana Limestone Belt," yielding much of the nations cut building limestone. The next zone east is a hilly upland developed on shale, with generally rather poor soil. The eastern margin of this upland forms "The Knobs," a picturesque line of high hills and bluffs as seen from the lowland just east. This lowland is the western margin of a gently sloping belt which extends from near the eastern margin of the state. This eastern slope was glaciated, but so long ago that any morainic clay remaining has been badly leached, and erosion has proceeded extensively. Indeed soil erosion is severe in all of southern Indiana but the small flat areas

Thus, in brief, despite Indiana's small size (36,000 square miles) and slight range in elevation (from 313 to 1285 feet) it possesses clearly discernable regional contrasts. Hence a summary of the average characteristics of the various subdivisions of the state contributes to understanding.

HISTORY OF SCIENCE

Chairman: S. S. VISHER, Indiana University

Paul Weatherwax, Indiana University, was elected chairman for 1949.

ABSTRACTS

The Wabash Academy of Science, WILL E. EDINGTON, DePauw University.—The Wabash Academy of Science was organized at Crawfordsville, in 1844. According to it's *Proceedings of the Eleventh Annual Meeting*, held in July, 1854, it had a membership of fifty-eight, including Ryland T. Brown, John Campbell, William Twining, J. S. Roughum, and others then prominent in Indiana science.

The Terre Haute Scientific Association, WILL E. EDINGTON, DePauw University.—The Terre Haute Scientific Association was active for some years in the 1880's. Its membership included members of the faculties of Rose Polytechnic Institute and of the Indiana State Normal School. In 1888 it sponsored a "microscopical Soiree," which lasted two evenings, at which twenty-seven displays of microscopic studies and specimens were presented.

The Second Decade of Purdue University's School of Pharmacy, C. O. LEE, Purdue University.—The present paper continues the one presented before the Academy last year on the first decade. During 1894-1903 the school of pharmacy first offered a two-year course leading to the degree of Pharmaceutical Chemist, and a four-year course leading to the degree of Bachelor of Science in Pharmacy. Purdue was thus among the leaders in offering the bachelor's degree in pharmacy. The paper also reports faculty personnel from year to year, curriculum changes, enrollment, and the number graduated.

Indiana Geologists Before 1900, CLYDE A. MALOTT, Indiana University.—The geology of Indiana has been the subject of study by a few geologists whose names are famous in American geology, but the presentation of much of the field details has been the work of local geologists. This is true not only for the period up to 1900, but up to the present time. J. P. Leslie and F. H. Bradley worked briefly in Indiana in 1859 and 1869, respectively. Leo Lesquereux, S. A. Miller, C. A. White, E. D. Cope, and James Hall contributed notably to the paleontology of Indiana in the 1870's and 1880's. Lesquereux was on the second Owen survey in 1859 and made a notable contribution to the knowledge of the coal bearing formations. Frank Leverett, T. C. Hopkins, and G. H. Ashley presented much field detail in Indiana geology in the 1890's. All of the official State Geologists of Indiana have been residents of the State and their reports constitute voluminous details on Indiana geology. D. D. Owen of New Harmony made a special geology survey of Indiana in 1837-38. A second special survey was made by R. T. Brown in 1851-53, and a third special survey was carried out by Richard Owen in 1859-61. E. T. Cox, also of New Harmony, was State Geologist for 10 years following the establishment of the Indiana Geological Survey in 1869. In the detailed county surveys of the Cox period, Rufus Haymond, John Collett, B. C. Hobbs, Robert Warder, W. W. Borden, M. N. Elrod, and E. S. McIntire did much of the field work for the Cox reports. John Collett followed as State Geologist and served until 1885. He employed the services of G. K. Greene, R. T. Brown, A. J. Phinney, D. S. M'Caslin, and M. N. Elrod. Maurice Thompson was appointed State Geologist in 1885 and served until 1888. His geological staff was composed of S. S. Gorby, A. J. Phinney, W. H. Thompson, R. T. Brown, and C. R. Dryer. S. S. Gorby was appointed State Geologist in 1889 and served until 1894. He was aided by, Maurice Thompson, M. N. Elrod, A. C. Benedict, E. P. Cubberly, and C. R. Dryer. The productive surveys of W. S. Blatchley began in 1895 and continued for a period of 16 years. Important geological investigations were carried on during the Blatchley period. His earlier staff was composed of C. E. Siebenthal, E. M. Kindle, J. T. Scovel, and J. A. Price, all local geologists, and in addition he had the specialists T. C. Hopkins and G. H. Ashley on the survey. Other geologists contributing to the geology of Indiana before 1900 were C. S. Beechler, V. F. Marsters, John Newsom, Joseph Moore, L. F. Bennett, A. C. Veatch, A. H. Purdue, W. A. McBeth, and Glenn Culbertson. Of the 44 geologists herein mentioned, 34 were residents or natives of Indiana.

Early Hoosier Archaeologists, GLENN A. BLACK, Indiana Historical Society, Angel Mounds.—John Collett, Sylvester S. Gorby, Edward T. Cox, Willis S. Blatchley and Rufus D. Hayman were geologists who took advantage of their intimate contact with the land to make archaeological observations. Many of these observations were made at an early date, and are in their published reports. As a result, those of us who are interested in the prehistory of Indiana have a record of much data that would otherwise have been lost.

A Study of the Indiana Scientists Sketched in American Men of Science, STEPHEN S. VISHER, Indiana University.—This paper is an extension to two hitherto presented before the Academy. (Two years ago, a statistical study of the Indiana scientists sketched in the 1944 edition of American Men of Science; a year ago, a fuller study of the Indiana scientists who have been starred as especially distinguished).

The present paper is an abstract of a study of all the scientists born, college trained or employed in Indiana who were sketched in any one of the seven editions of American Men of Science, 1906-1944. It is based on a card catalog of about 2850 scientists. Of these, nearly a half (1400) were born in Indiana, somewhat more than a half (1550) graduated from a college or university in Indiana, and about 1800 were employed in Indiana. Of those born in Indiana, about a third (463) went elsewhere for their advanced education and nearly two thirds (831) were employed elsewhere. Of those who were trained in Indiana (1807), about a half (945) were natives of the state and about two fifths (862) were employed at least for a time in Indiana.

Of those employed in Indiana, somewhat less than a third were born here, and nearly a half had part or all of the advanced training here. Thus only about two fifths (798) were neither born nor trained here.

These 2850 scientists list themselves, in their sketches in American Men of Science, in more than 97 sciences. For summary purposes they have been here assembled into nine groups. In order of size, these are: chemisty (773), biology (428), the medical sciences (389), engineering (274), mathematics and astronomy (228), physics (220), the agricultural sciences (177), psychology (137), geologists and geographers (132).

The leading two groups, chemists and biologists, lead in each of the three great categories here used (natives, college trained, and employed). The smaller groups displayed irregular variation; for example, fewer agricultural scientists have been employed in Indiana than of geologists and geographers, but fifty percent more agriculturists were trained here than geologists and geographers.

Of those born in Indiana, but neither educated nor employed here, about 45 percent are chemists or biologists (with 99 and 91 of the 425). Four of the other groups each had 30 to 36 persons of this category, while engineers had 46 and the medical group, 60.

Of those educated in Indiana, but neither born nor employed here, chemists led by a wide margin (86 of the 270); biologists, with 54, are second, and engineers, third. Only 8 geologists and geographers came into Indiana for their training and left soon afterwards.

Of those employed in Indiana, but neither born nor trained here, about 30 percent were chemists (225 of 782). Biologists were second (179) and engineers third (89).

Of those born and educated in Indiana but not employed here, the chemists made up nearly one-fourth (125 of 478). Biologists were 112, physicists, 91, while four other groups each had 32 to 38 in this category.

Only 51 of these 2850 scientists were both born and employed in Indiana but not educated here. By contrast, nearly a seventh of the total were educated and employed here (362 of 2850). A third of these are chemists and nearly a fourth are biologists.

Nearly a fifth of the scientists of Indiana were born, educated, and employed in Indiana. Of this group, biologists comprise 155 of the 491, chemists 103, physicists 57 and the other groups 26 to 47.

Thus it appears that approximately a third of the biologists, chemists, physicists, and engineers employed in Indiana were not born or trained here, while fewer than one-fourth of the agriculturists and geologists and geographers are in this category. Conversely, Indiana has been the birthplace and place of training of large numbers of scientists who found employment in other states.

Early Physics in Indiana (to 1900)

R. R. RAMSEY, Indiana University

About the only source of information about early Physics is that found in college catalogs. In England one could consult the various publications of the Royal Society, organized in 1660, and later societies. The Philosophical Transactions and the Proceedings of the Royal Society contain many articles pertaining to Physics.

The first meeting of the Royal Society was held at Gersham College. Thus early Physics as well as other branches of science has been associated with colleges since the beginning.

In Indiana we have very little or nothing handed down through learned societies until the founding of the Indiana Academy of Science in 1885. Thus our only source of information is from the early publications of the Indiana Colleges. The College Catalog was the only publication. This, in the early days, may be a sheet of four pages. This contains a list of the Trustees, of the Faculty, with their titles, a list of the students, and a course of study. In a sheet of four pages the information given in the Course of Study is necessarily rather meager.

Here I have made no attempt to consult college catalogs, other than those of Indiana University. So my source is Indiana University catalogs and the Proceedings of the Indiana Academy of Science.

Early Physics, or Natural Philosophy, is somewhat mixed with other sciences, such as Astronomy and Chemistry. In the early catalogs of Indiana University, Chemistry, Natural Philosophy, and Astronomy at times seem to have been given as one course. We find Chemistry, Heat, and Electricity listed as one course. Sometimes it is Chemistry, Acoustics, and Optics. Professors of Natural Philosophy seemed to be those who taught Mathematics, Physics, Chemistry, Astronomy, and perhaps Botany and Zoology. I suspect that some of these professors taught Latin and Greek in order to while away their spare time.

In the earliest catalog I found—1831—the name of Dr. John H. Harney, A.M., Professor of Mathematics and Natural and Mechanical Philosophy and Chemistry. There were three other names in the faculty list. In the list of studies for the junior year we find "Mathematics finished, Mechanics, Astronomy, Physics, Mathematical and Physical Geography." A statement is made that a "chemical and philosophical apparatus has been procured and the foundation of a well selected library has been made." It would be interesting to know just what a chemical and philosophical apparatus was.

The catalog of 1871 has lists of the teaching staff from 1832-1871. John H. Harney, 1831, is not mentioned in the list of Professors of Physical Science. However, the 1831 catalog has Natural Philosophy as one of the many subjects of which he was professor. The list of Professors of Physical Science 1832 to 1867 is as follows:

Ebenezer N. Elliott, A.M., 1832-37; Rev. Theopholis A. Wylie, A.M., 1837-53, 1855-63; Rev. Rovert Milligan, A.M., 1852-53; General Jacob Ammen, A.M., 1854, and Richard Dale Owen, M.D., 1863-67.

It states that Richard Dale Owen was elected Professor of Natural Science in 1867. The catalog of 1870 has Theopholis A. Wylie as Professor of Natural Philosophy, and Richard Dale Owen as Professor of Natural Science.

Thus starting with Harney 1831 as Professor of Natural Philosophy, we have a professor of Natural Philosophy or a professor of Natural Science from the beginning to 1871. Following this date we have Theopholis A. Wylie as Professor of Natural Philosophy or Professor of Physics until 1887, when Wylie is listed as Emeritus Professor of Physics.

In the catalog of 1837-38 where Theopholis Wylie is listed as Professor of Natural Philosophy and Chemistry we find the statement: "A laboratory and lecture room recently has been erected on the campus of the university. It offers to young gentlemen who intend ultimately to devote themselves to the Medical Profession great advantages." The catalog of 1860, where Professor Wylie is now listed as Professor of Natural Philosophy (chemistry is left out of his title), states that "The Chemical lectures and those in Natural Philosophy are illustrated in a series of experiments in the laboratory." About this time or somewhat before, this statement is found: "Additions have lately been made to the apparatus of the university, including a large Ruhmkerf coil, an improved air pump, a syren, and an Electro Magnetic Machine."

In 1885-86 Wylie is listed as Professor of Physics and J. P. Naylor as Associate Professor of Physics. In the 1886-87 catalog Wylie is Emeritus Professor of Physics. Having been Professor of Natural Philosophy from 1837 to 1886—fifty years if '37 and '86 is counted. J. P. Naylor is Acting head of Physics. The next year, 1867, Naylor is made Professor of Physics.

In 1886-87 under Naylor, the course in Physics at Indiana University was:

I Popular Lectures, with Gage as a text.
II Elementary Physics. Anthony and Brackett as text.
III and IV Laboratory Courses.
V Advanced Laboratory Studies, Thesis.

Naylor, a watch maker by trade, a born mechanic, and an industrious personage came at a time when electricity began to be useful and electrical apparatus was scarce and expensive. Naylor made the most of his apparatus. No sandpaper was allowed. The corners and edges had to be square and true. Naylor resigned to go to DePauw University as Professor of Physics in 1891. He told some one that he thought that DePauw has a greater future than Indiana University at that time, and DePauw also had a better ball team.

Associated with Professor Naylor during his last year was A. L. Foley as Instructor. In 1891-92 Benjamin F. Snow is listed as Professor of Physics on leave of absence. A. L. Foley as Associate Professor in charge of the Physics Department.

In 1892-93 Benjamin F. Snow, Professor, with A. L. Foley as Associate Professor. In 1893 Snow resigned to go to the University of Wisconsin as head of Physics. He remained at Wisconsin until he retired.

From 1893-96, Foley was in charge with Charles T. Knipp, Instructor. In 1896-97 Foley was on leave at Cornell. Knipp was in charge and Rolla R. Ramsey was Laboratory Assistant. In 1897-98, Foley was made Professor of Physics, with Knipp Instructor. In 1898-99 Knipp was on leave at Cornell. R. R. Ramsey Instructor.

In 1903 Knipp resigned to go to Illinois University, and R. R. Ramsey came as Assistant Professor.

Thus ends the Indiana University chapter, from 1831 to near 1900. No doubt a very similar chapter could be gleaned from the early catalogs of other Indiana colleges.

For my source of information about Indiana Physics in general I have consulted The Proceedings of the Indiana Academy of Science. The first meeting of the Indiana Academy of Science was at Indianapolis December 29, 1885. 1885 was the last year of Theopholis Wylie's career as active Professor at Indiana University, and the first year for J. P. Naylor. There were no published proceedings of the Academy until 1891.

The first published proceedings gives the programs of the previous meetings. Going through the programs and picking out the titles which seem to pertain to Physics, one finds the following men who gave papers.

As a parenthetic remark it should be said that in the early part of the nineteenth century Physics was mixed up with other branches and listed in general as Natural Philosophy. In the same manner near the end of the nineteenth century as well as in the twentieth century when some Physics had become "useful" we have it mixed up with—or perhaps it would be better to say it has been separated from the "useful." The "useful" has become Engineering. Some of the men whose names appear below were not teaching in Physics Departments. In Purdue University and Rose Polytechnic Institute they were listed as Electrical Engineers or Mechanical Engineers. As, in the twentieth century, we now have Radio Engineers, Acoustical Engineers, and Optical Engineers, we may expect in the near future to hear of Atomic Engineers, as soon as the atom has been put to useful rather than destructive purposes.

In the programs of the first six years 1885-91 of Indiana Academy we find J. P. Naylor giving papers in '85, '98, '90, and '91. Naylor is listed with Greencastle as his post office. However, Naylor did not leave Indiana University for DePauw University until 1891. So there may be some mistakes in my locations of other men. T. C. Mendenhall gave papers in '86, '88, and '90, address given as Washington, D. C.; Thomas Gray, papers in '88, '89, and '90, address Terre Haute; S. Lee Mees, papers in '88, '89, '90, Terre Haute; H. W. Wylie, in '88, paper titled "Refraction Index of Lard and Sorghum," probably at Lafayette at the time; E. G. Walters, '88, Lafayette; A. P. Carman, '88, '90, '91, Lafayette; J. E. Meers, '91, Richmond, Indiana; F. P. Starffer, '91, Logansport; R. A. Smart, '91, Lafayette; Mary Childs Noyes, '91, (?); F. M. Goss, '91, Lafayette; A. Wilmer Duff, '91, Lafayette; W. E. Goldsborough, '91, Lafayette; B. F. Snow, '92, Bloomington; A. L. Foley, '94, Bloomington; W. K. Hatt, '96, (not listed); C. T. Knipp, '96, Blomington; Fred Morley, '96, (?); S. N. Taylor, '96, W. Lafayette; A. L. Foley, '97, Bloomington; M. J. Golden, '99, Lafayette; J. L. Campbell, '99, Crawfordsville; E. S. Johannett, 1900, Terre Haute; Rolla R. Ramsey, 1903, Bloomington; Rolla R. Ramsey and Peter Haseman, 1904, Bloomington.

The above list gives names of men only. Some of these will be recognized as eminent men in other lines than Physics. Some to me are only names. I do not feel that I am qualified to comment on very many. Indiana cannot trace Physics back as far as the date of the beginning of the Royal Society 1660. However, if one considers the state of civilization and settlement of Indiana, the comparison between early Physics in Europe and early Indiana is very favorable.

A Brief History of the Conservation of Natural Resources in Indiana

H. H. MICHAUD, Purdue University

The early geological surveys in Indiana before the Civil War were conducted largely as investigations for exploring the possibility of developing the use of the natural resources like coal, limestone, gas, and oil. An act of the State Legislature, approved February 6, 1837, provided for a geological survey of Indiana. Dr. D. D. Owen was appointed as the first State Geologist and published a report on a "Geological Reconnaissance of the State of Indiana" for the year 1837.

Similar geological studies were continued for several decades by Dr. Owen and later by his brother, Dr. Richard Owen, who in his report for 1859-1860 included an analysis of the soils, a survey of the coal fields, and topographical work of the state.

In 1869, the Forty-sixth General Assembly of the state of Indiana created the office of the State Geologist, to act in connection with and under the control and management of the State Board of Agriculture, for the purpose of collecting information designed to promote the interests of agriculture, arts, manufactures, and minerals. Mr. E. T. Cox was appointed to the first office as State Geologist.

In the introduction to the first annual report of the State Geologist, Mr. Cox says, "Soon after receiving the appointment of State Geologist from his Excellency, Conrad Baker, Governor of Indiana, I proceeded to pack my large and valuable collection of minerals, fossils, shells, and other objects of natural history, also my chemicals and chemical apparatus, etc., etc., preparatory to making my residence in Indianapolis, and with a view of arranging them in the Geological Department of the State House.

"On arriving at the Capitol with this collection, it was soon made manifest that the room set apart for the use of the State Geologist was totally inadequate to hold the natural history specimens and chemical apparatus, and to be used at the same time, as office and laboratory.

"The State Officers, with one accord, decided to have a small addition, suitable for a chemical laboratory, built on the east side of the State House, adjoining the rooms of the Indiana Board of Agriculture.

"Thereupon began investigations of iron smelting and ores and fluxes used in the blast furnaces of Indiana. Other duties of the office included acting as counsellor and informant to people interested in investing capital for manufacturing enterprises in Indiana."

From the first and in the years following there were numerous accounts in the annual reports of the flora and fauna, especially of the timber resources, of the various counties of the state. Much attention was also devoted to the agricultural crop potential of the land.

A few examples are included at this point to emphasize the heavy impact of the early settlers on our natural resources and also the early recognition of the necessity of good farm conservation practices.

The first annual report for the year 1869 in a list of the birds and mammals of Franklin county says, "It is only within the last ten to fifteen years that the red fox has been observed in this county. Previously, none but the gray fox was seen." The wildcat was mentioned as rare, the raccoon abundant, the black bear was last seen about thirty years ago, (1839), although claw marks were still plainly visible on the beech trees. There were no more deer. The Parakeet and Ivory-billed woodpecker had not been seen for many years. The Passenger Pigeon was still found in large numbers although they were regarded as having been constantly reduced in the preceding forty years. The Wood Ibis occasionally visited the White River valley. Such were the original evidences of disappearing wildlife, nearly eighty years ago, caused by the early influence of clearing land for agriculture.

The 1872 Geological Report on Dearborn, Ohio, and Switzerland counties in practical suggestions on farm husbandry recognized the loss of soil fertility. It reads as follows: "The farmer's habits of observation enable him quickly to detect a field of natural fertility that has been worn out. By bad management it has been so changed that it will produce but one-half or one-third the crop that was raised on the virgin soil. The soil may lose its fertility by taking the products off the farm each year, leaving less plant food in the ground for the next crop. Some of the upland has been exhausted by raising corn so that it now is difficult to get grass well set."

Practices of good husbandry recommended (1) Sowing clover and turning under the green crop, (2) Sowing a crop of rye in the fall, clover in the spring, and turning in hogs in September for pasture, (3) Plowing in green manure and pasturing was insufficient so that additional fertilizer was needed, (4) Stable manure and rotten straw was highly recommended, (5) Experiments with lime were encouraged as results of this practice were not well known, (6) Crop rotation, and (7) the use of artificial fertilizers, it was suggested, should be used with caution.

The quite modern question, except for the figures, asked was, "But if a farm nets $10.00 per acre when a profit of $20.00 to $30.00 is within reach, is this not poor management?"

The 1875 report on the agriculture of Jefferson county says, "The potash and phosphates taken up by the crops as food must be returned to the soil, or the land will be impoverished to the amount abstracted from it." Again in 1881, speaking of the soil of Bartholomew county, the author says, "will the farmer husband this heritage or dissipate it by the slovenly methods of working his land and non-rotation of crops? A soil once exhausted, can only be brought back to fertility at great cost, and at the expense of some other locality that must furnish the necessary organic matter, or else wait years for it to be renewed by the slow processes of nature."

The 1876 report includes a record of the "Flora of the Lower Wabash Valley" by Schneck that is worthy of note. The circumference of trees measured three feet above ground were tabulated. The list included:

	Circumference
Pecan	16 feet
Bur Oak	22 feet
Black Walnut	22 feet
Mulberry	10⅓ feet
Sycamore	33⅓ feet
Tulip	25 feet
Cottonwood	22 feet

Of these trees the author made the following comments: "The measurements can only be regarded as those of a remnant of a once extensive, luxuriant and exceedingly massive growth of forest trees. Could they be compared with those that might have been taken fifty to seventy five years ago, they would doubtless be far surpassed. One cannot suppress a sigh of regret over the many prostrate and decaying bodies of those grand old monarchs of the forest, whose venerable lives have been sacrificed, when in their fullest manhood and grandeur, by the indefatiguable frontiersman, for a hive of honeybees or a raccoon that has sought refuge and a home in the hollows of their bodies or massive limbs.

While the wasteful destruction of timber has been great, yet it can in no way be compared with the amount annually taken from the woods for useful purposes. Scattered through the country, and at almost every bend in the river, will be found saw mills; some of which have been almost daily doing the work of destruction for the last fifty years. And of late, the more ravenous, portable saw mills have gone to the more inaccessible localities, until there is scarcely to be found a spot from which the best timber has not been culled. Judging from the past, it is safe to say: the time is not distant when there will scarcely be left a sample of these monuments of centuries growth."

Such were the ravages of the land that were well known and obviously were the concern of the conservationists in the last half of the nineteenth century in Indiana.

For many years the office of the State Geologist functioned primarily as the only agency of the state government concerned with natural resources. In the early part of the present century, numerous laws appeared for the protection of resources and the separate offices of Entomologist, the State Board of Forestry, the State Park Commission, and Superintendent of Fisheries and Game were added.

In 1919 the state legislature established the present Indiana Department of Conservation. The law provided a non-partisan Conservation Commission of four members, a Conservation Director responsible to the Commission and Directors for each of the Divisions of the Department. Richard Lieber, as first director, served until 1933. The original state owned lands totalled 2,766.11 acres including Clark County

State Forest; Riverside, Tri-lakes and Wawasee Fish Hatcheries; Turkey Run and McCormick's Creek State Parks. By comparison, state owned properties today include sixteen State Parks, sixteen State Forests, four State Game Reserves, fourteen State Memorials, and nine State Fish Hatcheries.

The aim of the Department of Conservation as expressed in a publication in 1919 entitled, "The Why and Wherefore of Conservation in Indiana" was "to make every Hoosier a conservationst, who believes in the state and the laws which are in force to conserve its natural resources for the benefit, education and recreation of all Hoosiers now and to come."

Some important strides in connection with the Indiana Department of Conservation have been made since 1919. The Forest Land Classification Act of 1921 has become one of the state's most potent vehicles for better forest protection, management and utilization on privately owned lands. Lands thus classified are designated by the state forester as eligible for the special assessment of only one dollar evaluation per acre. This tax savings inducement plus a more intelligent interest in forest conservation by 1946 was responsible for 120,000 acres of classified woods by twenty-two hundred private owners.

However, there are still approximately 800,000 acres of the state in need of reforestation. This is land unsuitable for farming and must be in trees to be productive. The annual nursery stock of about 4,500,000 trees is inadequate to supply the demand for foresting both public and private land. Present nurseries should be developed to provide 15,000,000 trees annually and the magnitude of the task is emphasized by the fact that fifty years would be required to reforest the land even at this annual production figure.

Wildlife research is made possible in Indiana, under the Pittman-Robertson Act (1937) through the cooperation of the United States Fish and Wildlife Service and the Indiana Division of Fish and Game. The act provides the states with aid in wildlife restoration projects, from funds obtained through a ten percent excise tax on the sale of sporting arms and ammunition. Seventy five percent of the funds used by these projects in the state (allocated to the states on the basis of the number of hunting licenses issued), are provided by the Federal Government and twenty five percent by the state.

Indiana has participated in this program since December 1, 1940. Provided that, in each case, the primary purpose is wildlife restoration, the funds may be used for three kinds of projects: (1) purchase of land, (2) development of land, and (3) research studies.

In Indiana, Pittman-Robertson funds have been used to help purchase the Hovey Lake State Game Preserve and additional acreage at the Jasper-Pulaski State Game Preserve. White-tailed deer have been bought for release in southern Indiana. Wildlife habitat areas on private lands have been developed and a continuous program of research has been in progress since 1940. Progress reports of this work are issued quarterly.

The County Forest Law, created to authorize county commissioners to acquire lands to establish county forests, the work of the Indiana Stream Pollution Control Board in cooperation with the State Board of Health, the Indiana Flood Control Commission and the excellent investigations of the more recent Division of Water Resources of the Department of Conservation should be mentioned as evidence of the growing demand on the part of the people for the conservation of the state's natural resources.

Not all of the influence for improved conservation practices have emanated from the Department of Conservation. During the thirties, the Land Use Planning Committees, composed of local farmers in every county of the state, were a potent force in developing the need for state-wide land conservation. These committees evaluated the farm land on the basis of the best use to which the farms of the county should be put and made recommendations as to the kind of crops that could be grown most advantageously.

The Soil Conservation Districts Law was passed by the Indiana legislature in 1937, amended in 1941 and 1945. Its purpose is expressed in the Declaration of Policy: "It is hereby declared to be the policy of the general assembly to provide for the conservation of the soil and the soil resources of this state, and for the control and prevention of soil erosion, and thereby preserve natural resources, control floods, prevent impairment of dams and reservoirs, assist in maintaining the navigability of rivers and harbors, preserve wildlife, protect the tax base, protect public lands and protect and promote the health, safety and general welfare of the people of the state."

Twenty five or more landowners (a large number is preferred) of a given area petition the State Soil Conservation Committee asking that a district be organized. A district may be county-wide, part of a county, or parts of more than one county. Most of them are organized on a county-wide basis.

After the State Committee examines and approves the petition, it conducts a public hearing, giving opportunity for all interested parties to be heard. If the hearing shows that a district is desirable, the boundaries are established and a referendum is held. Landowners may vote "for" or "against" the creation of a district. If sixty percent or more vote in favor, the State Committee may declare the district legally created.

There are now forty-one soil conservation districts in Indiana representing over seven thousand individual farm conservation plans, or about eight hundred and fifty thousand acres. These farms are exercising good land use through corrective farm practices like (1) contouring, (2) strip cropping, (3) terracing, (4) vegetated waterways, (5) improved crop rotations, (6) cover crops, (7) pasture improvement, (8) tree planting, (9) woodland management and, (10) use of farm ponds.

Considerable progress has been made in scientific research and public education. The Lake and Stream Studies conducted by Indiana University and the research in forestry and wildlife by Purdue University in cooperation with the State Department of Conservation have made possible many improvements in conservation practices. The results of research in good soils management, agronomy, and forestry and wildlife management have been made available to the farmer through the Agricultural Extension Service. Education in conservation for rural youth has been stimulated through the 4H Club projects and the annual 4H Club Conservation Camp at Versailles State Park.

A special program in conservation education for public schools was initiated in 1945. Through the cooperation of the State Office of Public Instruction, the Indiana Department of Conservation and Purdue University the program for the schools has included: (1) bulletins about soils, water, plants and wildlife conservation, (2) counselling with teachers and administrators and (3) a six weeks field course in conservation for teachers at Versailles State Park.

Several private industries and many non-profit organizations like the Women's Garden Clubs, Izaak Walton League Chapters and others have taken an active part in promoting this work in the schools and in giving financial support for local teachers to attend the summer camp.

Reference to past proceedings of the Indiana Academy of Science reveals that numerous papers have been devoted to native resources and their conservation, especially in geography, geology, botany, and zoology. The Academy, in some states, has seen fit to schedule a separate section on resource use. The Indiana Academy has not yet pooled its conservation interests in this manner, but as an effective force in molding scientific pursuit and thinking, such a move might be worthy of consideration.

Historical Landmarks of Chemotherapy

C. A. BEHRENS, Purdue University

The earliest history of medicine is that of ancient Egypt and reveals the fact that these primitive people searched the vegetable, animal and mineral kingdoms for substances which would be efficacious against disease.

During the 3000 year Pharaonic Dynasties, ending in 340 B. C., and the Chou Dynasty, 1130-250 B. C., chemicals were employed to combat disease. In the latter period mercurial ointments were used in the treatment of syphilis.

In the early middle ages Paracelsus (1493-1541) used lead, copper, mercury, and even derivatives of gold. Chemotherapy probably had its beginning with the work of Paracelsus in 1526. All of these substances were employed wholly in an empirical manner. These hit and miss methods undoubtedly met with success in some instances. Mercury was used by the Arabians for syphilis and they introduced it into Europe in the 16th century.

The Peruvian Indians of the 17th century used cinchona bark, a source of quinine, against remittent fever, malaria. Also, the Brazilians, according to the writings of Willem Piso (1611-1678), a Dutch physician, who visited South America in 1636-44, recognized the value of ipecacuanha root, ipecac, the active ingredient being emetin, for tropical amebic dysentery. Everything under the sun was tried sooner or later with the idea of changing the reaction of the blood in order to make it unfit for the parasite to develop in.

Discovery of antisera for tetanus and diphtheria in 1894 sidetracked this work. This was renewed in a different spirit in 1900 when protozoal parasites became important. Since that time the laboratory has accomplished wonders.

Real experimental chemotherapy began in 1904 with the significant experiments of Dr. Paul Ehrlich and his collaborators Ulenhuth and Shiga. Reported cures of mice suffering from the otherwise fatal trypanosomal disease of human sleeping sickness by a single injection of trypan red were announced. This dye and trypan blue were used in Leishmaniasis. Ehrlich visited this country in 1904. Ehrlich's aim was "Therapie Sterilisans Magna," to kill everything at once. He hoped to destroy the invading organism in one or two days by a single dose of the drug. The action was compared to a bullet going through the body and destroying the parasite but leaving the cells of the host unharmed. The goal was to find a chemical which had greater affinity for the parasite, that is, parasitotropic, than for the tissues of the host or organotropic.

Arsenic was used early in an empirical way. In 1850 David Livingston, a missionary to South Africa, administered arsenic to animals sick with tick-fever. There was a temporary improvement followed by decline, reappearance of the parasite and finally death ensued. In India, Lingard used arsenic in surra, a trypanosomal disease (Trypanosoma evansi) of horses, cattle, camels and elephants. Again there was usually death after temporary improvement. In 1903 Laveran, discoverer of the protozoan causing malaria in 1880, injected Fowler's solution (potassium arsenate) and noted the same results.

The parasites that survive the treatment become accustomed to the chemical and are no longer affected by it. Such organisms are known as "fast," "chemofast," "arsenic fast." Consequently, one must guard against such fastness in the treatment of disease. A rotation of different kinds of chemicals is used such as compounds containing arsenic, others bismuth and still others containing antimony.

Some of these synthesized preparations were effective in some diseases but gave no results with others. "Trypan blue" proved to be valuable in the treatment of parasites that cause the general disease known as piroplasmosis affecting mainly cattle but it is very disappointing in the treatment of trypanosomiasis.

Shortly after Laveran's report, Thomas (1905), an Englishman, showed that a proprietory organic arsenic preparation known as "atoxyl" was effective against trypanosomal infections. This announcement led to an expedition headed by Robert Koch to tropical East Africa for the purpose of trying "atoxyl" on natives suffering from sleeping sickness (trypanosoma gambiense). "Atoxyl" had marked effect upon the parasite but it was also very toxic to the host and consequently could not be used.

In 1905 Schandinn and Hoffmann announced the discovery of the causative organism of human syphilis (Treponema pallidum). All attempts to produce curative antisera failed. Ehrlich's trial experiments of the effect of arsenic compounds upon this treponema and relapsing fever spirochetes seemed promising. Through long tedious processes of elimination more and more effective arsenicals were synthesized. The 606th preparation seemed to have the properties of an effective agent. Experiments with syphilis infected rabbits gave startling results, the treponema was apparently destroyed, lesions healed and cure resulted.

Tests on syphilitic humans (luetics) were confirmed by animals. In 1909, "arsphenamine," its official name, was given to the medical profession. This was an epoch making discovery against a disease which for centuries was a curse to mankind. Metchinkoff and Roux in 1903 showed that calomel ointment when applied one or two hours after cutaneous inoculation with this treponema prevented infection. Arsenicals of this nature are also most effective for yaws, bejel, pinta and relapsing fevers.

Other developments such as the syntheses of trypanocides followed and in 1921 the Rockefeller Institute for Medical Research produced "tryparsamide." Its effectiveness against human sleeping sickness was established during an expedition to the Belgian Congo. The Germans synthesized "Bayer 205" or "germanin" in 1920. Three years later the

French prepared two very effective trypanocides, "Fourneau 270" or "arsanine" and "Fourneau 309" or "moranyl." The former is comparable to "tryparsamide" while the latter is similar to "Bayer 205."

Another important advance in chemotherapy was the discovery in 1921 of the value of bismuth compounds. These synthesized preparations greatly surpassed mercury as an effective antisyphilitic remedy. Such preparations are also used in combination with "arsphenamine."

Still another group of chemicals containing antimony have been synthesized. These antimonials are especially effective against the various types of Leishmaniasis. As early as 1913 Vianna employed antimony tartrate in these infections.

There was much interest manifested in the development of new antimalarials and in 1926 "plasmochin" was synthesized. It is claimed that "plasmochin" is effective against all the different types of malaria including the pernicious form which does not respond to quinine.

Another effective antimalarial is "atabrin" which is less toxic than either quinine or "plasmochin." This complex chemical was first synthesized by Mauss and Mietsch in 1933. This yellow, bitter tasting, fluorescening powder destroys the schizonts while "plasmochin" is a gametocide.

The exact synthesis of the alkaloid quinine was accomplished by Robert B. Woodard, Harvard, and William E. Doering, Columbia, in 1944.

Bacterial Chemotherapy

The greatest triumphs in chemotherapy were against protozoal and spirochetal infections. Since most of the infectious diseases of man are caused by bacteria, it was of prime importance to discover specific chemicals for bacterial diseases.

It was at first thought that bacteria were too simple in structure to lend themselves to treatment by chemicals which in turn would not be toxic to the host. Koch in 1881 failed at bacterial chemotherapy in anthrax of guinea-pigs. Many attempts were made on various laboratory animals with practically no success until 1911 when Morganroth and Levy reported a cure of mice suffering from pneumonia following injections of ethylhydrocuprein. However, it possessed no clinical value because the curative dose was too near the lethal one. The discovery of the group of "sulfonamide" chemicals as therapeutics completely altered the situation.

The historical landmarks of bacterial chemotherapy briefly are as follows: In 1908 P. Gelmo, a student at the University of Vienna, synthesized "sulfanilamide" from coal tar for his Ph. D. degree. His work was forgotten for over twenty years but was again brought to light in 1930 when Fritz Mietzsch and Joseph Klarer, who had just completed the synthesis of "atabrin," began their experiments on bacterial chemotherapy. For some reason or other they decided to use "sulfanilamide," Gelmo's synthesis, as a starting point. In 1933 Dr. Forrester saved the life of a ten-months-old boy who was dying from staphylococcus septicemia following injections of "streptozon" which was thought to be effective against streptococci. It's name was then changed to "prontosil." This was the first evidence that Mietzsch and Klarer had succeeded. They patented this azo dye in 1932. Domagk in 1935 cured mice and rabbits suffering from streptococcal infections with "prontosil." His published results awoke the world to the fact that a new chemical against bacterial diseases was at hand. Domagk's work was shortly, thereafter, confirmed by Levaditi and Vaisman in France and Colebrook and Kenny in England. Next in 1936 Jacques, Trefouels, Nitti, Dovet of the Pasteur Institute in France and Buttle, Gray and Stephenson in England showed that the simple "sulfanilamide" fraction, which it will be called was prepared by Gelmo in 1908, of the complex "prontosil" was alone the effective agent against bacterial infections, and also, was much less toxic. Thus, the patents on the azo dye "protosil" were valueless.

Ehrlich's purpose of chemotherapy was to destroy all the invading organisms by a single injection of the chemical. However, satisfactory results in the use of these chemicals depends upon two things: Effective blood concentration and a sufficient duration of this concentration. That is, the dose is not the amount of the chemical given but rather should be in terms of blood concentration and duration of time.

Many thousands of chemicals of the sulfonamide type have been tested in mice but only a relatively few, sulfanilamide, sulfadiazine, sulfapyridine, sulfathiazole, sulfaguanidine, and succinylsulfathiazole are employed against diseases of man.

Antibiotics as Therapeutic Agents

Pasteur in 1877 observed that, when animals, susceptible to anthrax, were injected with the bacillus contaminated with certain organisms, infection often failed. Later in 1889 it was shown that sterilized cultures of the bacillus of green pus, Pseudomonas pyocyaneus, and culture filtrates, pyocyanase, were effective when injected into rabbits suffering from anthrax. The action of pyocyanase, however, was not substantiated.

In 1929 Professor Alexander Fleming at St. Mary's Hospital, London, discovered "penicillin" a most effective antibiotic against bacterial infections. Penicillin was obtained from a specific kind of a common green mold, *Penicillium notatum.*

In 1936 Professor H. W. Florey and associates at Oxford University, England, began to investigate the action of "penicillin" and in 1940 isolated it in the form of a brown powder.

Dubos of the Rockefeller Institute in 1939 discovered the antibiotic "gramicidin." Waksman in 1944 gave us "streptomycin" and Meleney in 1947 "bacitracin." Antibiotic substances are produced by actinomycetes, algae, bacteria, fungi and green plants. Millions of experiments are being conducted in order to discover more effective antibiotics. One of the latest to be announced is "circulin" by Drs. Murray and Tetrault of Purdue University. It's effectiveness is especially against so-called Gram negative microorganisms.

And so, as the use of chemicals against disease goes on, this quotation from Sophocles, made about 500 years B. C. in his drama, "Antigone," becomes more and more realistic, "Only against death shall he call for aid in vain, but from the baffling maladies he hath devised escape."

Early Studies on Protoplasm

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Introduction

The active living substance of both plant and animal cells, which we now call protoplasm, has interested and baffled man since its discovery three centuries ago. Its importance is recognized in such phrases as the statement that protoplasm is "the physical basis of life" and in present-day definitions which point out that protoplasm is "the essential material of which living creatures are composed."

Current knowledge indicates that every living cell contains a small quantity of protoplasm. The bulk of this protoplasm is usually cytoplasm, which in plant cells, abuts upon the surrounding cell wall. This cytoplasm is believed to function under the control of a directing nucleus which is generally confined within the cell unit. Here the nucleus lies submerged in, or surrounded by, the cytoplasm.

Most cells are vacuolated, that is to say they contain one or more vacuoles, or resevoirs, which are filled with water and various solutes. Mature plant cells, in contrast to those of animals, usually contain one large vacuole which occupies the bulk of the cell. In these cells, the cytoplasm is confined to a thin layer along the wall, plus occasional strands, which may stretch across the vacuole. The nucleus is found either in the sytoplasm adjacent to the wall, or suspended in the vacuole by means of strands of cytoplasm and enclosed in a thin envelope of the same material.

The Pre-protoplasmic Era

In 1665, the English natural philosopher, Robert Hooke, published his "Micrographia" in which he described numerous observations made with a microscope of his own design. Hooke who had broad interests in the field of science, was a mathematician, a physicist, an inventor, a surveyor, an architect, and a doctor of medicine. He served as curator for the Royal Society for over forty years. While not a biologist by training or profession, it was his good fortune to be the first to publicize the cellular structure of plant tissues.

Although his first recorded observations were made upon the structure of non-living cork, Hooke also reports that further observations were made upon thin sections of living plant tissues. These objects he likewise found to possess cellular structure. This was as far as Hooke's curiosity led him, for he turned his attention to other things and left the careful study of plant structure to workers of the next decade.

From the English Hooke we pass to Leeuwenhoek of Holland, a contemporary who outlived Hooke by twenty years. Leeuwenhoek was a master builder of microscopes of original design. Although his were simple microscopes, each containing but a single lens, yet his skillful grinding and choice of materials were such that he obtained magnifications of as high as 270 diameters.

With the aid of these microscopes, Leeuwenhoek made a very great many observations and discoveries of tremendous importance to biology. For example he observed and accurately described one of the smallest of man's cells, the red blood corpuscle. He also observed the cells of yeast plants, the eggs of weevils and of flies, and the spermatozoa of dogs and man. His superior lenses and keen eyesight enabled him to discover the existence of protozoa and finally, to climax his previous work, to see and describe bacteria for the first time. This he did in 1683 at the age of sixty years.

It remained, however, for the Italian physician Malpighi and his English medical contemporary Grew to use the microscope as a tool for the patient, minute study of higher forms of living organisms. Both Malpighi (1679) and Grew (1682) published independently an "Anatomy of Plants" in which the structures of organs and tissues were painstakingly detailed in terms of the tiny cells of which they are built. While the work of Malpighi and Grew stressed the different tissues which were constituent parts of the organisms they studied, yet the smallest unit of structure, the cell, is shown in their drawings in easily recognizable form.

"Sarcode"

As far as known, neither Hooke nor the keen-sighted Leeuwenhoek, nor even the students of plant anatomy-Malphigi and Grew-ever clearly saw living protoplasm. If they did, no importance was apparently attached to such an observation. This can be explained on the grounds that, owing to imperfections in the microscopes of the seventeenth century, accurate observations upon the internal structure of living cells were out of the question. It remained, therefore, to the workers of the 18th century to begin this phase of cellular investigation. According to some authors, it was the Italian "cytologist" Corti, who in 1772 early observed and reported the existence of the slimy substance present in living cells. That Corti followed up this observation is shown by the fact that he discovered currents existing within the cell. This flowing movement we now speak of as protoplasmic streaming. Corti's observation upon protoplasmic streaming was later substantiated by Treviranus, a German botanist and professor at Bonn.

But progress in the field was extremely slow since it waited upon the further development of the microscope. This did not come until early in the nineteenth century, when microscopes with achromatic lenses began to appear in the laboratories of biological institutions. Thus it happened that the eighteenth century was, on the whole, relatively fruitless in the production of new knowledge of the cell.

With the improved microscopes which were put into use during the first half of the nineteenth century, much light was thrown upon the internal structure of cells. The name of Felix Dujardin (1801-1860) stands out among those who contributed most to this new knowledge. Although trained in art and engineering, Dujardin early developed into one of the leading French biologists. In 1835 he published a paper which, according to a modern authority (Seifriz), contains an accurate description of protoplasm that has not been greatly improved upon to this day. This paper was one of a series "Investigations on the lower organisms" and was entitled "On the supposed stomachs of Infusoria and on a substance called 'Sarcode'." A translation of his description is as follows: "Thus I propose to name that which some other observers have called a living jelly, that glutinous, transparent substance, insoluble in water, contracting in globular masses, adhering to the dissecting needles, and allowing itself to be drawn out like mucus; finally, occurring in all lower animals interposed, on the other structural elements."

Dujardin called attention to the ability of "sarcode" droplets, which were caused to emerge from a protozoan parasite of the earthworm, to produce film formation around the droplets, although this was known to occur only in certain cases.

In a later work (1841) the same author pointed out another property of "sarcode," namely that of forming vacuoles. He says: "But the strangest property of sarcode is the spontaneous production, within its mass, of vacuoles or small spherical cavities." This property of vacuolization Dujardin pointed out, distinguished protoplasm from gelatin, mucus, or albumin and was observed to take place in protozoa following injury.

A contemporary of Dujardin was Dutrochet, the discover of osmosis. This worker, 1837, published a note in Comptus Rendus concerning the effect of temperature, mechanical irritation, salts, acids, alkali, narcotics, and alcohol upon protoplasmic streaming in the alga Chara. He found that streaming took place slowly, even at temperatures as low as melting ice, but increased rapidly with a rise in temperature. Dutrochet also stated that mechanical pressure, when exerted on a plant cell can cause the cessation of protoplasmic streaming.

Another contributor to our knowledge of the cell is the Scottish botanist Robert Brown. Brown, who is the discover of the random motion of particles which bears his name, published in 1831 his discovery of the nucleus or "areola" as he also called it. This important protoplasmic structure he discovered in the epidermis of members of the orchid family, and later demonstrated it in a great number of other plant cells.

Protoplasm

We owe the term "protoplasm" to the Czech scientist Purkinje. This term was derived from the Greek "protos" meaning first and "plasma" meaning form. As used by Purkinje, the term was applied to the formative material of animal eggs and embryos, and was introduced in 1839.

In 1864, there appeared one of a long list of important papers from the pen of the German scientist von Mohl. Von Mohl began his career as a doctor of medicine, then he became professor of physiology, and finally professor of botany. Additional traits include those of a modest and reserved man of science who was able to observe and evaluate known facts in a careful and accurate manner.

In his paper Von Mohl applied the term "protoplasm" to the living substance in plant cells and showed that the "sarcode" of animal cells and the protoplasm of plant cells are essentially the same. Von Mohl described protoplasm in a paper entitled "On the fluid movement in the interior of cells" as "never a clear watery cell fluid but a viscous stringy mass."

Further properties of protoplasm were recorded by Carl Nägeli, a Swiss botanist contemporary with Von Mohl. Nägeli verified the membrane formation taking place at the surfaces of exuded drops of protoplasm. He observed the formation of protoplasmic strands in plasmolyzed Spirogyra cells. These strands, when cut, contracted and pulled back into the main mass of protoplasm. Nägeli, also studied the influence of temperature on protoplasmic streaming, the formation of vacuoles in degenerating plant protoplasm, and the killing of algal cells by dilute solutions of copper and mercury salts.

Before going on to the "protoplasm doctrine" of Max Schultze, let us "turn back the clock" some twenty years and touch upon the cell-theory concept. In 1838, Matthais Jacob Schleiden published an essay entitled "Contribution to Phytogenesis" which forms the first installment of what is now known as the "cell theory." Schleiden was the son of a Hamburg physician and studied jurisprudence, then became a doctor of law, and later a barrister in his home town. At this point in his career, matters took a strange turn. Proving to be unsuccessful at law, Schleiden became despondent and shot himself in the head. In this, he was also unsuccessful, and upon recovery resolved to devote his life to natural science. This he did and thereby gained lasting fame.

In discussing the question of how cells arise, Schleiden emphasized the importance in cell division of the recently discovered nucleus and uncovered the fact that the embryo arises from a single cell. He stressed the cell as an independent unit, presenting, at the same time, the plant as a community of cells.

These concepts applied to plants by Schleiden were extended the following year to animals by the German zoologist, anatomist, and discover of pepsin, Theodor Schwann. He states: "The elementary parts of all tissues are formed of cells in an analogous, though very diversified manner, so that it may be stated that there is one universal principle of development for the elementary parts of organisms, however different they may be, and that this principle is the formation of cells." The importance of these conclusions is pointed out by J. A. Thomson in his book "The Great Biologist." He says "To see many things as one, is one of the ends of science, and the cell-theory gave a new unity to the whole range of animate nature."

While Schleiden and Schwann have usually been given the credit for originating and publicizing the "cell theory," earlier work on this subject should not be ignored. According to Raber, Dutrochet had previously (1824) "(1) established the anatomical individuality of cells, (2) described the universal cellular structure of living plant and animal tissues, and (3) stressed the importance of the cell as the physiological unit of the organism."

In spite of the importance of the views presented by the proponents of the cell theory, their concepts were restricted too much to walls or other cell boundaries. Less attention was given to the living content of the cells and its importance in the physiology of living things. This misconception was corrected by Max Schultze in a short essay entitled "On muscle bodies and what one calls a cell" which appeared in 1861. Schultze had devoted himself to the extensive study of microscopic subjects including single celled animals, leuconsites, and nerve and muscle tissues. From these studies he became convinced that the most essential thing in a cell is not, as his predecessors had stated "a vesicle surrounded by a membrane, with a nucleus and fluid contents," but a mass of protoplasm with a nucleus. Thus to Schultze, the word "cell" becomes, illogically perhaps, the vital "element" represented by the nucleus and accompanying protoplasm. The cell envelope, be it wall or membrane, assumes when present a role of lesser importance. This is in keeping with our modern conception of the life and the component parts of the cell.

Conclusion

We have attempted to trace the development of the concept of structural and functional unity of living organisms from early beginnings up to a climatic statement which gives Schultze's viewpoint of nearly 90 years ago, but which even now represents sound physiological views. In other words, we still hold (to quote Raber) "that the important physiological and morphological unit of all organized life is the nucleated mass of protoplasm."

This does not then mean, of course, that no advancement has been made in subsequent study. Microscopes of greater power and refinement, improved techniques in handling the experimental material, and new knowledge in the fields of colloid chemistry and related sciences have all contributed to aid in man's study of protoplasm. At the same time, the protoplasmic system appears to be so complex, the organization so intricate, and the equilibra so sensitive that a complete understanding of the stuff which we all call protoplasm is not by any means "just around the corner."

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Starred Scientists Born or Trained in Indiana

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Indiana was the state of birth of 81 starred scientists and the state in which 80 received their collegiate training. These Indiana scientists are about 3.6 percent of all the starred scientists who were born in the United States or received their college training here. They were starred in one or more of the seven editions of "American Men of Science" as especially distinguished in research. The voting was by secret ballot of the leaders in their science. Twenty-eight were starred in the first edition (1906), 11 to 13 in the second (1910), third (1921), and seventh (1944) editions, and 4, 5, or 8 in the other editions.

As part of an effort to learn more about what conditions are conducive to high achievement, the published data on the places of birth and of training of the starred scientists have been studied in considerable detail. In addition, a comprehensive questionnaire was sent in November, 1946, to those living, asking, among other questions, what influences they considered to have been most significant in their own case.

The present article is an abstract of some of the data on the scientists who were born in Indiana or who received their college degree there.

Yield in Proportion to Population

Indiana is exceeded in yield of starred scientists per million of population at their average date of birth by the New England States, the other East North Central States, by half of the West North Central States, and by New York, New Jersey, Delaware, Maryland and Wyoming. Indiana exceeds the remaining states, most of them by a wide margin. For example, Indiana's total yield per million of population is more than 10 times that of Arkansas, Mississippi, or Oklahoma and more than 5 times that of Alabama, Georgia, Louisiana or New Mexico. It was more than 3 times that of North Carolina, West Virginia, Kentucky, Tennessee, Florida or North Dakota. It was more than twice that of South Carolina, Virginia, Colorado, Montana, Utah or Oregon.

In the yield of *botanists*, Indiana was surpassed only by 8 states (Connecticut, Massachusetts, Vermont, New York, Illinois, Michigan, Wisconsin, and Nebraska). In the yield of *zoologists*, Indiana was surpassed by only 10 states (New England, except R. I., New York, Kansas, Minnesota, Maryland). In the yield of *psychologists*, Indiana was surpassed only by 8 states (New England, Utah and Wyoming). For *astronomers*, Indiana was surpassed by 12 states (New England, Ohio, Illinois, Michigan, Minnesota, Colorado and California). As to *anatomists*, Indiana was surpassed by 14 states; as to *anthropologists*, by 4 states; as to *chemists*, by 15 states; as to *geologists*, by 17 states;

as to *mathematicians*, by 16 states; as to *pathologists*, by 12 states; as to *physicists*, by 25 states; and as to *physiologists*, by 12 states. Thus Indiana's rank among the states was lowest as to physicists and relatively low as to geologists, chemists, mathematicians.

Table 1 gives the number of these scientists born in Indiana by decade of birth and by science. It reveals that half of the total were born in the 20 years 1860-1879, 30 were born since 1880, none since 1904. The yield of starred scientists per million of population was about 11 for the 1870's, 10 for the 1860's, 6 for the 1880's and somewhat more than 3 per million for the 1890's and 1900's. The causes for these changes in productivity are significant, and merit discussion.

Table 1 also shows that nearly one-fourth, 19, were starred in zoology, while 12 were starred in botany, 11 in chemistry and 6 or 7 each in geology, physics or psychology. Each of the 12 sciences in which starring has been done is represented by 2 or more Hoosiers. The relatively large numbers starred in zoology reflects the influence of David Starr Jordan. Several of the botanists were students of John Merle Coulter.

TABLE 1. Native Indiana Starred Scientists
Number born by science and decade of birth

Born	before 1860	1860's	1870's	1880's	1890's	1900's	1910's	Total
Anatomy	0	0	1	0	1	0	0	2
Anthropology	0	1	1	0	0	0	0	2
Astronomy	2	0	1	2	0	0	0	5
Botany	1	5	3	2	1	0	0	12
Chemistry	2	0	2	1	3	3	0	11
Geology	1	3	1	0	0	1	0	6
Mathematics	0	2	2	0	0	0	0	4
Pathology	1	1	0	1	0	1	0	4
Physics	1	2	0	0	2	2	0	7
Physiology	0	1	1	1	0	0	0	3
Psychology	0	3	1	1	1	0	0	6
Zoology	3	3	7	5	0	1	0	19
Totals	11	21	20	13	8	8	0	81
Population Mid-Year Millions	1.2	1.5	1.8	2.1	2.35	2.6		
Yield per Million	9.1	10.0	11.0	6.2	3.4	3.1	0	

Areal Contrasts in Yield of Scientists

List 1 gives by science the names of the starred scientits born in Indiana, with the year and place of their birth, and list 7 presents the birth places by counties. When these birth places are mapped, it is seen that just half of the counties yielded no starred scientists, and a quarter of them yielded only one each. By contrast, Marion County yielded 5, Switzerland, Johnson and Wayne counties each 4, and Jefferson, Union, Hancock, Allen and Vigo 3 each. The yield by quarters of the State's population at the median date of the birth of these 81 scientists (1875) is as follows: the southeast quarter was the birthplace of 29 scientists, giving a yield of 14.5 per 100,000 of population. The northeast quarter yielded 23, or 11.5 per 100,000 population. The southwest yielded 19 or 9.5 per 100,000. The northwest yielded 11, or 5.5 per 100,000. Thus the southeast quarter did nearly three times as well as the equally populous northwest, and the northeast fully twice as well. The eastern half of the state's population yielded 63.5% of the total number, the southern half yielded 58.5%.

The unglaciated part of the State yielded 8 starred scientists, or at a rate of 4.8 per 100,000 of population. The relatively prosperous lower Wabash Valley Lowland of the southwestern part of the State, south of Terre Haute, yielded only one starred scientist. These 9 southwestern counties yielded starred scientists at the rate of one per 220,000 people. Fifteen northwestern counties having a combined population of 250,000 people yielded none. Two of these northwestern counties contain Wabash College and Purdue University. Why should 15 counties east and southeast of Marion County having a combined population of 284,000 people yield 30 starred scientists or one per 9,500 people while a similar number of counties in the northwest having as many people yielded none?

Theories as to Regional Contrasts in Yield

Seven theories as to the yield of notables are:

1. That leaders come from especially prosperous areas. This certainly is not true for all of Indiana. Crawford and Switzerland counties, two of the poorest in the State, yielded at the rate of 1 scientist per 4,200 people, while Benton, Howard, Rush, Blackford, Knox and many other rich counties with a combined population of much more than 200,000 people yielded not one starred scientist.

2. Another theory is that notable leaders come largely from areas which are educationally favored. In Indiana, for example, the counties containing Earlham and Franklin colleges and DePauw and Indiana universities yielded 10 starred scientists, one-eighth of the total number, although at the average date of birth of the scientists these counties contained only 95,000 people, or somewhat less than one-twentieth of the state's population. But on the other hand, 5 of the 6 counties which had the highest yield of starred scientists in proportion to population lacked colleges. These especially productive counties were Union,

Switzerland, Jefferson, Hancock, and Parke, with a total yield of 13 starred scientists from a population of 82,000 people, or an average of one scientist for 6,300 people. (Union and Switzerland counties did twice as well as this average). These 5 counties yielded starred scientists at about 50 percent higher rate than did the best 4 counties with colleges.

3. A third theory to explain the regional contrasts in yield of outstanding leaders is that they come from the culturally more advanced areas, not from frontiers. The Indiana data lends some support to this theory, as the southeastern part of the State was the first to be well-peopled, while the northwest was settled latest. However the inadequacy of this explanation is indicated by the fact that several parts of the state settled early yielded no starred scientist; an example is the southwestern part, Vincennes and Washington south to the Ohio River. Crawfordsville was another early cultural center which has yielded no starred scientists, although several have graduated from Wabash College. And Tippecanoe County, containing Purdue, has yielded none.

4. A fourth theory is that the distribution is erratic, a matter of chance. This theory is disproved by many data. The more the subject is studied, the more evidence is disclosed that "it is not mere chance."

5. A fifth theory is that wherever economic and cultural conditions are at least fairly favorable, the areal differences in yield of notables correlates with contrasts in the quality of segments of the population. In Indiana, a considerable number of the starred scientists were descendents of persons who left Germany in 1848 or soon thereafter, partly because they sought greater freedom from the oppression then imposed. Several other Indiana-born scientists were the children of Quakers or of Scotch Presbyterians who had come to Indiana from the Carolinas before the Civil War partly because they disapproved of slavery. The Quaker group, which settled largely fairly near Richmond (where they established Earlham College) yielded several of the starred scientists of Union, Wayne, and Randolph counties, and also the two from Parke County and the one from Orange County. The Scotch Presbyterians were less concentrated; they yielded several of the 81. Several other Indiana starred scientists had Puritan ancestors. Puritan "stock" has been especially productive of starred scientists, according to the returns from Cattell's 1904 and the present author's 1946 questionnaire, and to much other evidence. Most of the starred scientists born in northern Indiana had Puritan ancestors as did several of those born in southern Indiana.

6. A sixth theory is that outstanding leaders such as the starred scientists come from families that are especially alert, earnest, and ambitious, without respect to their racial backgrounds, and that such people tend to congregate in places of comparative opportunity for them to use their talents. Bits of evidence from the data as to the Indiana starred scientists which supports this theory include: When southeastern Indiana was relatively favored, it produced many leaders, but when, because of the depletion of soil and forest wealth and especially when greater opportunities opened elsewhere, many of the more ambitious

people moved away. As a result, southeastern Indiana has yielded few starred scientists for many years. For example none were born since 1880 in four of the southeastern counties which were especially productive earlier (Crawford, Jefferson, Switzerland or Union counties). Likewise not one was born since 1880 in the entire unglaciated part of the State. Indeed, all 42 counties south of Wayne, Johnson and Vigo have yielded only two since 1881, one born in 1887 (Mann), and the other in 1901 (Twitty). Another evidence of the selective migration of the parents of the starred scientists is that relatively many starred scientists were born in county seats, the local centers of greatest opportunity for talent. The considerable number born in college towns is another evidence. The fact that of the 30 born in Indiana since 1880, 12 were born in the Gas Belt of the late 1880's and 1890's is significant. The boom experienced there attracted relatively many ambitious people. Both of Indiana's Nobel Prize winners, Urey and Stanley, were born in the northern half of the State since 1892.

7. A seventh theory to explain the contrasts in yield of notables is that, from young people with the requisite ability, leaders come if they receive adequate encouragement from those close to them and from stimulating teachers, provided opportunities are afforded to them to develop their talents. Conversely, few become such leaders if sufficiently stimulating teachers are not available, and if they are not encouraged to prepare themselves adequately, and if opportunities to serve as leaders are not available. This theory has much support in Indiana.

Starred Scientists who Obtained College Degrees in Indiana

Of the 81 native starred scientists, 49 obtained their college degrees in Indiana and 31 graduated elsewhere, (one, Mooney, did not graduate). However, those who went elsewhere for their college training were matched by 31 who came from other states or countries to Indiana for their college degrees.

Table 2 shows by science and decade of graduation the number of starred scientists who received college degrees in Indiana. It reveals that 19 zoologists graduated in Indiana, 16 botanists, 13 chemists, 11 physicists, 8 psychologists, 7 astronomers, 2 each of anthropology, mathematics and physiology, 1 each of geology and pathology and none in anatomy. The available data indicate that of the 19 zoologists, 5 were students of David Starr Jordan and 8 studied under students of his who later taught in Indiana. In addition, several of Dr. Jordan's students were later starred in other sciences than zoology and gave him much credit for his having stimulated them to high achievement. Of the 16 botanists, about 5 were students of John Merle Coulter and 4 or 5 were students of his former students who later taught in Indiana. Of the 13 chemists, 4 graduated at DePauw, 2 of them under W. M. Blanchard; 3 graduated at Earlham and one each at Butler, Hanover, Manchester, Notre Dame, Purdue and Valparaiso. Of the 11 physicists, 4 graduated at DePauw, 3 at Indiana, and 2 each at Purdue and Rose

TABLE 2. Indiana colleges starred scientists collegiate alumni
Number by Science and Date of Graduation

	Before 1880	1880-1884	1885-1889	1890-1894	1895-1899	1900-1904	1905-1909	1910-1914	1915-1919	1920-1931
Anthropology	0	0	0	1	1	0	0	0	0	0
Astronomy	0	0	1	1	0	3	2	0	0	0
Botany	3	0	2	6	0	1	2	2	0	0
Chemistry	3	0	0	2	2	1	0	1	0	4
Geology	0	0	0	1	0	0	0	0	0	0
Mathematics	0	0	1	0	0	1	0	0	0	0
Pathology	0	0	1	0	0	0	0	0	0	0
Physics	0	1	0	5	1	1	1	0	0	2
Physiology	0	0	0	0	0	1	0	1	0	0
Psychology	0	1	0	2	0	1	2	1	1	0
Zoology	1	0	4	1	4	5	3	0	0	1
	7	2	9	19	8	14	10	5	1	7

Polytechnic, none elsewhere. Of the 8 psychologists, Indiana graduated 5, Earlham, Evansville and Valparaiso 1 each (Stone graduated from both Valparaiso and Indiana University). Of the 7 astronomers, Indiana graduated 5, of whom 4 were students of the other one, John A. Miller. The remaining 2 were from Rose Poly and Valparaiso. The 2 anthropologists graduated at Earlham and I. U. The 2 mathematicians graduated at I. U. and Purdue; also graduated at I. U. were the 2 physiologists, the geologist, and the pathologist. (The names of these alumni are given in lists 2-5).

Table 2 shows that the number of subsequently starred scientists who obtained their college degree in Indiana fluctuated among the half decades. During 1890-1894, 19 graduated, during the next half-decade 8, but during 1900-1904, 14. Conversely, only 1 graduated 1915-1919, although 7 graduated since 1919. Why not? What happened at Indiana University, for example, which caused it to graduate 5 in 1902 and 8 in 1903-1906 but only two since then? Of 266 men who graduated there in the 1880's, 5 were starred; of the 833 who graduated in the 1890's, 11 were starred; of the approximately 800 who graduated 1900-1906, 14 were starred. For 1907-1929 inclusive about 8000 men were graduated from I. U. Of these only 2 were starred. Thus nearly 2 percent of the graduates of the 1880's later were starred, 1.3 percent of the graduates of the 1890's, 1.6% of those of 1900-1906, less than 0.1% of those of the next decade and none at all since then!

The fluctuation in the proportion of the alumni who subsequently were starred correlates with several conditions, including changes in the faculty, changes in institutional policies, changes in size of enrollments and classes, changes in opportunities, changes in the age of the faculty. The large number of graduates of 1902-1906 who became distinguished scientists clearly merits special consideration. Apparently the coming of W. L. Bryan to the presidency in 1902 and the establishment of the Graduate School aroused hopes and greatly stimulated various students. Why the drastic decline after 1906? Apparently this was partly due to failure of the expectations aroused in 1902 to materialize. Significant also was the sharp increase in enrollments which occurred then, and the relatively great growth of the law school and medical school. Moreover since about 1907 many of the students taking zoology have done so because it is one of the requirements for admission to medical school, not because they were especially interested in zoology. Such students tend to divert students who had planned on becoming scientists. Other factors influencing the decline were the relatively notable advancement in certain other universities, and the greater opportunities in business. (Gary was founded in 1906 and industrialization developed rapidly in Indiana following 1906.) The progressive aging of the faculty also played a part. In 1902, most of the faculty were relatively young. Many of them continued in power, as heads of their departments, for some decades. When President Bryan retired in 1937, at the age of 77, many of the department heads and deans were elderly and, as is true of most elderly persons, no longer optimistic and enthusiastic.

List 2 gives by science and institution the names of the collegiate alumni, with the year of their graduation. (Stone received two bachelors degrees. Pike is listed under both zoology and physiology.)

As a sort of appendix are given 6 lists. List 3 gives by schools their starred alumni; List 4 and 5 give these by year of graduation, with some summary data. List 6 gives, alphabetically, the names of the 81 starred scientists born in Indiana. List 7 gives them by counties. List 8 gives those 31 born elsewhere who received college degrees in Indiana. At the end there is a summary and some conclusions.

LIST 1. INDIANA STARRED SCIENTISTS, BIRTHPLACES BY SCIENCE

With Year of Birth Given After the Name

Anatomy: (2) A Kuntz '79 (Batesville, Ripley Co.,); W. F. Windle '98 (Huntington, Huntington Co.).

Anthropology: (2) J. Mooney '61 (Richmond, Wayne Co.); C. Wissler '70 (Wayne Co.).

Astronomy: (5) C. L. Doolittle '43 (Ontario, Lagrange Co.); J. C. Duncan '82 (Knightstown, Hancock Co.); J. A. Miller '59 (Greensburg, Decatur Co.); Slipher, E.C. '83 & V.M. '75 (Mulberry, Clinton Co.).

Botany: (12) C. R. Barnes '58 (Madison, Jefferson Co.); H. L. Bolley '65 (Holman, Dearborn Co.); O. W. Caldwell '69 (Lebanon, Boone Co.); H. M. Fitzpatrick '86 (Greenwood, Johnson Co.); R. B. Harvey '90 (Monroeville, Morgan Co.); D. T. MacDougal '65 (Liberty, Union Co.); G. T. Moore '71 (Indianapolis, Marion Co.); D. M. Mottier '64 (Patriot, Switzerland Co.); E. W. Olive '70 (Lebanon, Boone Co.); J. N. Rose '62 (Union Co.); J. R. Schramm '85 (Hancock Co.); H. H. Whetzel '77 (near Avilla, Noble Co.).

Chemistry: (11) R. F. Bacon '80 (Muncie, Delaware Co.); G. L. Clark '92 (Anderson, Madison Co.); A. C. Cope '09 (Dunreith, Henry Co.); M. R. Fenske '04 (Michigan City, LaPorte Co.); C. A. Kraus '75 (Knightsville, Clay Co.); S. A. Lattimore '28 (Liberty, Union Co.); H. N. McCoy '70 (Richmond, Wayne Co.); W. A. Noyes, Jr. '98 (Terre Haute, Vigo Co.); L. I. Smith '91 (Indianapolis, Marion Co.); W. M. Stanley '04 (Ridgeville, Randolph Co.); H. W. Wiley '44 (Kent, Jefferson Co.)

Geology: (6) H. F. Bain '71 (Seymour, Jackson Co.); C. P. Berkey '69 (Goshen, Elkhart Co.); O. P. Hay '46 (Jefferson Co.); E. M. Kindle '69 (Franklin, Johnson Co.); P. B. King '03 (Richmond, Wayne Co.); F. B. Taylor '60 (Ft. Wayne, Allen Co.).

Mathematics: (4) O. E. Glenn '78 (Moorefield, Switzerland Co.); E. R. Hedrick '76 (Union City, Randolph Co.); D. N. Lehmer '67 (Somerset, Wabash Co.); J. B. Shaw '66 (Remington, Jasper Co.).

Pathology: (4) J. S. Billings '38 (Switzerland Co.); G. F. Dick '81 (Fort Wayne, Allen Co.); T. Francis, Jr. '00 (Gas City, Grant Co.); A. S. Warthin '66 (Greensburg, Decatur Co.).

Physics: (7) L. A. DuBridge '01 (Terre Haute, Vigo Co.); A. L. Foley '67 (Hancock Co.); W. H. Furry '07 (Prairietown, Vigo Co.); E. Merritt '65 (Indianapolis, Marion Co.); W. B. Nottingham '99 (Tipton, Tipton Co.); J. O. Reed '56 (Newcastle, Henry Co.); H. C. Urey '93 (Walkerton, St. Joseph Co.).

Physiology: (3) R. Burton-Opitz '75 (Ft. Wayne, Allen Co.); C. W. Greene '66 (Crawford Co.); F. C. Mann '87 (Decatur, Adams Co.).

Psychology: (7) G. W. Allport '97 (Montezuma, Parke Co.); W. L. Bryan '60 (Bloomington, Monroe Co.); J. F. Dashiell '88 (Southport, Marion Co.); E. H. Lindley '69 (Paoli, Orange Co.); E. D. Starbuck '66 (Bridgeport, Marion Co.); C. P. Stone '92 (Portland, Jay Co.); L. M. Terman '77 (Johnson Co.).

Zoology: (19) W. C. Allee '85 (Bloomingdale, Parke Co.); B. M. Allen '77 (Greencastle, Putnam Co.); A. M. Banta '77 (Greenwood, Johnson Co.); G. N. Calkins '69 (Valparaiso, Porter Co.); C. Grave '70 (Monrovia, Morgan Co.); C. W. Hargitt '52 (Lawrenceburg, Dearborn Co.); G. T. Hargitt '81 (Fairfield, Franklin Co.); O. P. Hay '46 (Jefferson Co.); H. Heath '68 (Vevay, Switzerland Co.); W. T. Hornaday '54 (Plainfield, Hendricks Co.); C. Juday '71 (Ligonier, Noble Co.); C. H. Kennedy '79 (Rockport, Spencer Co.); W. L. McAtee '83 (Jalapa, Grant Co.); N. E. McIndoo '81 (Lyons, Greene Co.); W. J. Moenkhaus '71 (Huntingburg, DuBois Co.); F. Payne '81 (Shelbyville, Shelby Co.); J. Reighard '61 (LaPorte Co.); O. Riddle '77 (Crawford Co.); V. C. Twitty '01 (Martin Co.).

LIST 2. STARRED COLLEGIATE ALUMNI OF INDIANA BY SCIENCE

Anthropology: *Earlham:* Goddard, P. E. '92; *Indiana:* Wissler, C. '97.

Astronomy: *Indiana:* Duncan, J. C. '05; Lampland, C. O. '02; Miller, J. A. '90; Slipher, E. C. '06; Slipher, V. M. '01. *Rose Polytechnic Inst.:* Parkhurst, J. A. '86; *Valparaiso:* Anderson, J. A. '00.

Botany: *DePauw:* MacDougal, D. T. '90; *Earlham:* Petry, L. D. '07; *Franklin:* Caldwell, O. W. '94; *Hanover:* Barnes, C. R. '77; Coulter, J. M. '70; Coulter, S. '77 *Indiana:* Bray, W. L. '93; Mottier, D. M. '91; *Purdue:* Bolley, H. L. '88; *Valparais :* LaRue, C. D. '10; *Wabash:* Moore, G. T. '94; Olive, E. W. '93; Reddick, D. '05; Rose, J. N. '85; Schramm, J. R. '10; Whetzel, H. H. '02.

Chemistry: *Butler:* Cope, A. C. '29; *DePauw:* Bacon, R. F. '99; Clark, G. L. '14; Fenske, M. R. '25; Lattimore, S. A. '50; *Earlham:* Howe, H. E. '01; Stanley, W. M. '26; Warder, R. B. '66; *Hanover:*

Wiley, H. W. '67; *Manchester:* Flory, P. J. '31; *Notre Dame:* Nieuwland, J. A. '99; *Purdue:* McCoy, H. N. '92; *Valparaiso:* Teeple, J. E. '93.

Geology: *Indiana:* Kindle, E. M. '93.

Mathematics: *Indiana:* Glenn, O. E. '02; *Purdue:* Shaw, J. B. '89.

Pathology: *Indiana:* Warthin, A. S. '88.

Physics: *DePauw:* Furry, W. H. '28; Longden, A. C. '81; Stewart, G. W. '98; Stewart, O. M. '92; *Indiana:* Brown, F. C. '04 Foley, A. L. '90; Knipp, C. T. '94; *Purdue:* Luckiesh, M. '09; Nottingham, W. B. '20; *Rose Polytech. Inst.:* Johonnott, E. S. '93; Mendenhall, C. E. '94.

Physiology: *Indiana:* Mann, F. C. '11; Pike, F. H. '03.

Psychology: *Earlham:* Mills, W. R. '08; *Evansville:* Dashiell, J. F. '08; *Indiana:* Bryan, Wm. L. '84; Lindley, E. H. '93; Starbuck, E. D. '90; Stone, C. P. '15; Terman, L. M. '02; *Valparaiso:* Stone, C. P. '10.

Zoology: *Butler:* Gilbert, C. H. '79; Twitty, V. C. '25; *DePauw:* Allen, B. M. '98; McFarland, F. M. '89; Riley, W. A. '97; *Earlham:* Allee, W. C. '08; Grave, C. '95; *Indiana:* Banta, A. M. '03; Edwards, C. L. '86; Eigenmann, C. H. '86; Evermann, B. W. '86; Juday, C. '96; Kennedy, C. H. '02; McAtee, W. L. '04 McIndoo, N. E. '06; Moenkhaus, W. J. '94; Payne, F. '05; Pike, F. H. '03; Riddle, O. '02.

LIST 3. STARRED COLLEGIATE ALUMNI OF INDIANA SCHOOLS

Butler: (3) *Chemistry:* Cope, A. C. '29 *7; *Zoology:* Gilbert, C. H. '79 *1; Twitty, V. C. '25 *6.

DePauw: (12) *Botany:* MacDougal, D. T. '90 *1; *Chemistry:* Bacon, R. F. '99 *3; Clark, G. L. '14 *5; Fenske, M. R. '25 *7; Lattimore, S. A. '50 *1; *Physics:* Furry, W. H. '28 *7; Longden, A. C. '81 *1; Stewart, G. W. '98 *1; Stewart, O. M. '92 *1; *Zoology:* Allen, B. M. '98 *2; McFarland, F. M. '89 *1; Riley, W. A. '97 *5.

Earlham: (8) *Anthropology:* Goddard, P. E. '92 *3; *Botany:* Petry, L. D. '07 *6; *Chemistry:* Howe, H. E. '01 *3; Stanley, W. M. '26 *7; Warder, R. B. '66 *1; *Psychology:* Miles, W. R. '08 *4; *Zoology:* Allee, W. C. '08 *3; Grave, C. '95 *1.

Evansville: (1) *Psychology:* Dashiel, J. F. '08 *5.

Franklin: (1) *Botany:* Caldwell, O. W. '94 *2.

Hanover: (4) *Botany:* Barnes, C. R. '77 *1; Coulter, J. M. '70 *1; Coulter, S. '77 *1; *Chemistry:* Wiley, H. W. '67 *1.

Indiana: (32) *Anthropology:* Wissler, C. '97 *1; *Astronomy:* Duncan, J. C. '05 *6; Lampland, C. O. '02 *3; Miller, J. A. '90 *3; Slipher, E. C. '06 *5; Slipher, V. M. '01 *3; *Botany:* Bray, W. L. '93 *1; Mottier, D. M. '91 *1; *Geology:* Kindle, E. M. '93 *3; *Mathematics:*

Glenn, O. E. '02 *3; *Pathology:* Warthin, A. S. '88 *1; *Physics:* Brown, F. C. '04 *3; Foley, A. L. '90 *1; Knipp, C. T. '94 *1; *Physiology:* Mann, F. C. '11 *4; Pike, F. H. '03 *3; *Psychology:* Bryan, Wm. L. '84 *1; Lindley, E. H. '93 *1; Starbuck, E. D. '90 *2; Stone, C. P. '15 *5; Terman, L. M. '02 *3; *Zoology:* Banta, A. M. '03 *3; Edwards, C. L. '86 *1; Eigenmann, C. H. '86 *1; Evermann, B. W. '86 *2; Juday, C. '96 *4; Kennedy, C. H. '02 *7; McAtee, W. L. '04 *6; McIndoo, N. E. '06 *7; Moenkhaus, W. J. '94 *2; Payne, F. '05 *3; Pike, F. H. '03 *3; Riddle, '02 *3.

Manchester: (1) *Chemistry:* Flory, P. J. '31 *7.

Notre Dame: (1) *Chemistry:* Nieuwland, J. A. '99 *5.

Purdue: (5) *Botany:* Bolley, H. L. '88 *1; *Chemistry:* McCoy, H. N. '92 *2; *Mathematics:* Shaw, J. B. '89 *1; *Physics:* Luckiesh, M. '09 *3; Nottingham, W. B. '20 *7.

Rose Polytechnic Institute: (3) *Astronomy:* Parkhurst, J. A. '86 *2; *Physics:* Johonnott, E. S. '93 *2; Mendenhall, C. E. '94 *1.

Valparaiso: (4) *Astronomy:* Anderson, J. A. '00 *3; *Botany:* LaRue, C. D. '10 *6; *Chemistry:* Teeple, J. E. '93 *4; *Psychology:* Stone, C. P. '10 *5.

Wabash: (6) *Botany:* Moore, G. T. '94 *1; Olive, E. W. '93 *2; Reddick, D. '05 *3; Rose, J. N. '85 *1; Schramm, J. R. '10 *3; Whetzel, H. H. '02 *3.

LIST 4. STARRED COLLEGIATE ALUMNI

By School and Year of Graduation

Butler: (3) 1879 Gilbert; 1925 Twitty; 1929 Cope.

Depauw: (12) 1850 Lattimore; 1881 Longden; 1889 McFarland; 1890 MacDougal; 1892 Stewart, O. M.; 1897 Riley; 1898 Allen; Stewart, G. W.; 1899 Bacon; 1914 Clark; 1925 Fenske; 1928 Furry.

Earlham: (8) 1866 Warder; 1892 Goddard; 1895 Grave; 1901 Howe; 1907 Petry; 1908 Allee; Miles; 1926 Stanley.

Evansville: (1) 1908 Dashiell.

Franklin: (1) 1894 Caldwell.

Hanover: (4) 1867 Wiley; 1870 Coulter, J. M.; 1877 Barnes; Coulter, S.

Indiana: (32) 1884 Bryan; 1886 Edwards; Eigenmann; Evermann; 1888 Warthin; 1890 Foley; Miller; Starbuck; 1891 Mottier; 1893 Bray; Kindle; Lindley; 1894 Knipp; Moenkhaus; 1896 Juday; 1897 Wissler; 1901 Slipher, V. M.; 1902 Glenn; Kennedy; Lampland; Riddle; Terman; 1903 Banta; Pike; 1904 Brown; McAtee; 1905 Duncan; Payne; 1906 McIndoo; Slipher, E. C.; 1911 Mann; 1915 Stone.

Manchester: (1) 1931 Flory.

Notre Dame: (1) 1899 Nieuwland.

Purdue: (5) 1888 Bolley; 1889 Shaw; 1892 McCoy; 1909 Luckiesh; 1920 Nottingham.

Rose Polytechnic Institute: (3) 1886 Parkhurst; 1893 Johnnott; 1894 Mendenhall.

Valparaiso: (4) 1893 Teeple; 1900 Anderson; 1910 LaRue; Stone.

Wabash (6) 1885 Rose; 1893 Olive; 1894 Moore; 1902 Whetzel; 1905 Reddick; 1910 Schramm.

LIST 5. STARRED COLLEGIATE ALUMNI OF INDIANA BY CLASS

1850 Lattimore, S. A. 1866 Warder, R. B. 1867 Wiley, H. W. 1870 Coulter, J. M. 1877 Barnes, C. R.; Coulter, S. 1879 Gilbert, C. H. 1881 Longden, A. C. 1884 Bryan, Wm. L. 1885 Rose, J. N.; 1886 Edwards, C. L.; Eigenmann, C. H.; Evermann, B. W.; Parkhurst, J. A. 1888 Bolley, H. L.; Warthin, A. S. 1889 McFarland, F. M.; Shaw, J. B. 1890 Foley, A. L.; MacDougal, D. T.; Miller, J. A. Starbuck, E. D. 1891 Mottier, D. M. 1892 Goddard, P. E.; McCoy, H. N.; Stewart, O. M. 1893 Bray, W. L.; Johonnott, E. S.; Kindle, E. M.; Lindley, E. H.; Olive, E. W.; Teeple, J. E. 1894 Caldwell, O. W.; Knipp, C. T.; Mendenhall, C. E.; Moenkhaus, W. J.; Moore, G. T. 1895 Grave, C. 1896 Juday, C. 1897 Riley, W. A.; Wissler, C. 1898 Allen, B. M.; Stewart, G. W.

1899 Bacon, R. F.; Nieuwland, J. A. 1900 Anderson, J. A. 1901 Howe, H. E.; Slipher, V. M. 1902 Glenn, O. E.; Kennedy, C. H.; Lampland, C. O.; Riddle, O.; Terman, L. M.; Whetzel, H. H. 1903 Banta, A. M.; Pike, F. H. 1904 Brown, F. C.; McAtee, W. L. 1905 Duncan, J. C.; Payne, F.; Reddick, D. 1906 McIndoo, N. E.; Slipher, E. C. 1907 Petry, L. D. 1908 Allee, W. C.; Dashiell, J. F.; Miles, W. R. 1909 Luckiesh, M. 1910 LaRue, C. D.; Schramm, J. R.; Stone, C. P. 1911 Mann, F. C. 1914 Clark, G. L. 1915 Stone, C. P. 1920 Nottingham, W. B. 1925 Fenske, M. R.; Twitty, V. C. 1926 Stanley, W. M. 1928 Furry, W. H. 1929 Cope, A. C. 1931 Flory, P. J.

Before 1870 3; 1870's 4; 1880-84 2; 1885-89 9; 1890-94 19; 1895-99 8; 1900-04 12; 1905-09 10; 1910-14 5; 1915-19 0; 1920-24 1; 1925-29 4; 1930-1.

Every year 1884-1914 had 1 to 6.

Since 1914 only 7 have graduated, 6 of them 1915-1931.

The high years were 1893 and 1902, 6 each; 1894 5, in 1886 and 1890 4, and 3 each in 1905, 1908, 1910.

LIST 6. STARRED SCIENTISTS BORN IN INDIANA

Arranged Alphabetically; Year of Birth

Allee, W. C. '85; Allen, B. M. '77; Allport, G. W. '97; Bacon, R. F. '80; Bain, H. F. '71; Banta, A. M. '77; Barnes, C. R. '58; Berkey, C. P. '67;

Billings, J. S. '38; Bolley, H. L. '65; Bryan, W. L. '60; Burton-Opitz, R. '75; Caldwell, O. W. '69; Calkins, G. N. '69; Clark, G. L. '92; Cope, A. C. 1909; Dashiell, J. F. '88; Dick, G. F. '81; Doolittle, C. L. '43; DuBridge, L. A. 1901; Duncan, J. C. '82; Fenske, M. R. 1904; Fitzpatrick, H. M. '86; Foley, A. L. '67; Francis, T., Jr. 1900; Furry, W. H. 1907; Glenn, O. E. '78; Grave, C. '70; Greene, C. W. '66; Hargitt, C. W. '52; Hargitt, G. T. '81; Harvey, R. B. '90; Hay, O. P. '46; Heath, H. '68; Hedrick, E. R. '76; Hornaday, W. T. '54.

Juday, C. '71; Kennedy, C. H. '79; Kindle, E. M. '69; King, P. B. 1903; Kraus, C. A. '75 Kuntz, A. '79; Lattimore, S. A. '28; Lehmer, D. N. '67; Lindley, E. H. '69; MacDougal, D. T. '65; Mann, F. C. '87; McAtee, W. L. '83; McCoy, H. N. '70; McIndoo, N. E. '81; Merritt, E. '65; Miller, J. A. '59; Moenkhaus, W. J. '71; Mooney, J. '61; Moore, G. T. '71; Mottier, D. M. '64; Nottingham, W. B. '99; Noyes, W. A., Jr. '98; Olive, E. W. '70; Payne, F. '81; Reed, J. O. '56; Reighard, J. '61; Riddle, O. '77; Rose, J. N. '62 Schramm, J. R. '85; Shaw, J. B. '66; Slipher, E. C. '83; Slipher, V. M. '75; Smith, L. I. '91; Stanley, W. M. 1904; Starbuck, E. D. '66 Stone, C. P. '92; Taylor, F. B. '60; Terman, L. M. '77; Twitty, V. C. 1901; Urey, H. C. '93; Warthin, A. S. '66; Whetzel, H. H. '77; Wiley, H. W. '44 Windle, W. F. '98; Wissler, C. '70.

List 7. Starred Scientists Born in Indiana

Arranged by Counties

Adams: Mann; *Allen:* Burton-Opitz, Dick, Taylor; *Boone:* Caldwell, Olive; *Clay:* Kraus; *Clinton:* Slipher, E. C. and V. M.; *Crawford:* Greene, Riddle; *Dearborn:* Bolley, Hargitt, C. W.; *Decatur:* Miller, Warthin; *Delaware:* Bacon; *Dubois:* Moenkhaus; *Elkhart:* Berkey; *Franklin:* Hargitt, G. T.; *Grant:* Francis, McAtee; *Greene:* McIndoo; *Hancock:* Duncan, Foley, Schramm; *Hendricks:* Hornaday; *Henry:* Cope, Reed; *Huntington:* Windle; *Jackson:* Bain; *Jasper:* Shaw; *Jay:* Stone; *Jefferson:* Barnes, Hay, Wiley; *Johnson:* Banta, Fitzpatrick, Kindle, Terman; *LaGrange;* Doolittle; *LaPorte;* Fenske, Reighard; *Madison:* Clark; *Marion:* Dashiell, Merritt, Moore, Smith, Starbuck; *Martin:* Twitty; *Monroe:* Bryan; *Morgan:* Grave, Harvey; *Noble:* Juday, Whetzel; *Orange:* Lindley; *Parke:* Allee, Allport; *Porter:* Calkins; *Putnam:* Allen; *Randolph:* Hedrich, Stanley; *Ripley:* Kuntz; *St. Joseph:* Urey; *Shelby:* Payne; *Spencer:* Kennedy; *Switzerland:* Billings, Glenn, Heath, Mottier;*Tipton:* Nottingham; *Union:* Lattimore, MacDougal, Rose; *Vigo:* DuBridge, Furry, Noyes; *Wabash:* Lehmer; *Wayne:* King, McCoy, Mooney, Wissler.

List 8. Starred Scientists Who Came to Indiana for Their College Degrees

Anderson, J. A.; Bray, W. L.; Brown, F. C.; Coulter, J. M.; Coulter, Stanley; Edwards, C. L.; Eigenmann, C. H.; Everman, B. W.; Flory, P. J.; Gilbert, G. H.; Goddard, P. E.; Johonnott, E. S.; Howe, H. E.; Knipp, C. T.; Lampland, C. O.; LaRue, C. D.; Longden, A. C.; Luckiesh, M.; McFarland, F. M.; Mendenhall, C. E.; Miles, W. R.; Nieuwland, J. A.; Parkhurst, J. A.; Petry, L. D.; Pike, F. H.; Reddick, D.; Riley, W. A.; Stewart, G. W.; Stewart, O. M.; Teeple, J. E.; Warder, R. B.

Summary and Conclusions

Indiana was the native state of 81 scientists starred in the biographical directory, "American Men of Science," (by secret vote of their fellow scientists) as especially distinguished in research. Each of the 12 sciences in which starring has been done have had 2 or more representatives born in Indiana; zoology had 19, botany 12, chemistry 11, physics 7, geology 6, psychology 6, astronomy 5, mathematics and pathology 4 each, physiology 3, and anatomy and anthropology 2 each, For 7 sciences, Indiana surpassed more than three-fourths of the 48 states in the yield of starred scientists per million of population at about the date of their birth. For 3 sciences (anatomy, chemistry and mathematics) it surpassed two-thirds of the states and it stood only a little lower for geology. Only for physics was it surpassed by slightly more than half of the states.

The birthplaces of these scientists are very unequally distributed over the state. In brief, of those born before 1880, the southeastern part of the state led by a wide margin, but of those born since 1880 the southern part of the state yielded few. Contrasts among the counties and sections of the state are presented in some detail, and several possible explanations of the contrasts are offered.

Indiana institutions conferred college degrees upon 81 subsequently starred scientists, 31 of whom were born elsewhere. By institutions Indiana University graduated 32, DePauw 12, Earlham 8, Wasbash 6, Purdue 5, Hanover and Valparaiso 4, Butler and Rose 3, and Evansville, Franklin, Manchester, and Notre Dame 1 each. Considerable evidence, summarized in the paper, indicates that personal encouragement by enthusiastic, stimulating teachers was an important influence in the output of subsequently starred scientists. For example, 13 of the 19 zoologists were students of David Starr Jordan or of men started by him. In addition, several of Dr. Jordan's students were starred in other sciences. Of the 16 botanists, about 10 were students of John Merle Coulter or of students of his. John A. Miller trained most of the astronomers. W. M. Blanchard trained 2 of the chemists. Conversely, despite very large enrollments in chemistry for many decades, only one Purdue alumnus has been starred in chemistry and none from Indiana University. This suggests that large classes, sort of mass production methods, are not conducive to stimulating young people to become scholars. What is needed in addition to able students is individual attention and personal encouragement.

MATHEMATICS

Chairman: L. H. WHITTCRAFT, Ball State Teachers College

Paul Overman, Purdue University, was elected chairman for 1949.

ABSTRACTS

PHYSICS

Chairman: J. C. HENDRICS, Franklin College

Ancil R. Thomas, Valparaiso University, was elected chairman for

ABSTRACTS

Metastable Atomic States in Gas Discharges. K. W. MEISSNER, Purdue University.—The behaviour of a discharge through gases can be considerably influenced by the presence of atoms in metastable states. A simple experiment with a glow discharge in very pure neon strikingly shows such an influence in the following manner.

A glow discharge is maintained in a simple discharge tube of 25 millimeter diameter and 150 millimeter length which has been filled with very pure neon of about 5 mm Hg. The operating voltage is chosen in such a way that the discharge remains just stable. As soon as the glowing neon tube is irradiated with light of an intensive neon discharge tube the glow discharge becomes unstable and goes out. The explanation of this behaviour can be found in the fact that the number of metastable atoms is greatly reduced by absorption of certain wavelengths of the irradiating source.

Investigations With a Reflection Echelon Grating. DELMAR O. DAVIS, K. W. MEISNER, Purdue University.—The performance of a reflection echelon grating made by Adam Hilger, Ltd., London, was investigated.

The possibility of changing from a "double-order" pattern to a "single-order" pattern by changing the geometrical conditions instead of the commonly used change of air pressure is discussed and the idea was tested experimentally. It was found that a slight change of the angle of incidence allows one to produce a change of a whole order. This fact is of great importance for investigations in the vacuum ultraviolet.

The accuracy of wave length measurements is not affected by the choice of the angle of incidence as was shown by wave length measurements of krypton and neon lines.

Last, the effective resolving power of the reflection echelon was determined by using the Zeeman effect of the 5570 A krypton line. The smallest Zeeman splitting which could be resolved by the echelon was taken as the limit of resolution. It was found that the reflection echelon achieves, in practice, the theoretical resolving power.

Neutron Diffraction by Ice Crystals. HUBERT M. JAMES, Purdue University.—X-ray studies have established the positions of the oxygen atoms in ice crystals, but determination of the positions of the hydrogen atoms has not been possible. Neutron diffraction offers a powerful method for locating the hydrogen atoms, but interpretation of the diffraction patterns obtained by Wollan and Shull at Oak Ridge has offered difficulties which are apparently connected with other peculiarities in the behavior of ice—the presence of unexplained diffuse bands in the X-ray spectrum, and the unexpectedly large value of the entropy. It is known that each oxygen atom has four oxygen neighbors, tetrahedrally arranged, and on each oxygen-oxygen line one must expect to find one hydrogen atom. Pauling has accounted for the observed entropy of ice by assuming that each hydrogen atom can occupy two alternative and unsymmetrical positions with equal probabilities, subject to the condition that of the four hydrogen neighbors of each oxygen, two must be in the position nearer to this oxygen, and two in the more remote positions. A calculation has been made of the neutron diffraction patterns to be expected for a single ice crystal, on Pauling's model. This consists of three parts:

> (a) Laue spots, with intensities predictable by assigning half the scattering amplitude of each hydrogen nucleus to the two alternative positions for that nucleus.
>
> (b) A continuous background arising from the randomness in the arrangement of the hydrogen muclei.
>
> (c) A background showing some structure due to the correlations established between the positions of hydrogen atoms by the condition that each oxygen atom shall have exactly two close hydrogen neighbors.

Dr. Wollan informs the author that the observed intensities of the Laue spots agree well with this prediction.

The Determination of the Deflective Curve of a Vibrating Beam by Means of Bonded Strain Gages. B. E. QUINN and JAMES E. BROCK, Purdue University.—An experimental method is described for securing strain vs. time records at significant points along a vibrating beam by means of bonded strain gages. A simple transformation gives

$$\frac{d^2y}{dx^2} = \frac{\epsilon}{c}$$

where ϵ is strain and c is the distance from the neutral axis to the extreme fiber. If we plot ϵ/c vs. length for any instant, then it is possible by means of two successive graphical integrations to plot the deflection curve. The determination of other properties of the vibrating beam from the ϵ/c vs. length curve is also explained.

PSYCHOLOGY

Chairman: Douglas G. Ellison, Indiana University

E. J. Asher, Purdue University, was elected chairman for 1949.

ABSTRACTS

Application of Servo Theory to Human Motor Behavior. D. G. Ellson, Indiana University.—Servo theory was developed by engineers and mathematicians to aid in the design of mechanical and electrical transmission systems and amplifiers. With the aid of this theory the performance of a complex transmission system can be improved by designing one component so that its performance characteristics match certain characteristics of other components. "Noise" or errors introduced by one component can be eliminated or filtered out by suitable design of other components.

A man operating certain types of machines such as an automobile, an airplane, or a gunsight may be considered as one component of a complex system which includes both the man and the machine. If the man's response in operating the machine has the necessary characteristics for the application of servo theory, then it may be possible to eliminate the errors which the man makes by proper design of the machine he operates. The psychological problem on which research is being done at present is the investigation of the response characteristics necessary for this application.

A Re-Test of Adolescents' Interpretations of Emotionally-toned Situations After Two Years. Alma Long, Purdue University.—Comparison of responses of 76 youths whose records were part of the large number studied for development of measuring devices, after a period of two years. Original classification in grades 7-10. Identical materials and methods for test-retesting.

Studied for indications of consistency in individual response, extent and nature of change, implications for school and counselling needs. About one third of group (1) Maintained same relative rank in group, (2) Progressed farther than average for age-grade group, (3) Lost ground in social position, respectively.

Change in relative position showed little relationship to differences in intelligence ranking or to measures of home quality. Nature of responses, where serious loss in relative position occurred, indicates need for much greater knowledge about and attention to the social needs and personal satisfactions of high school pupils, and to those of the younger pupils in particular.

Prediction of the Relationship Between Test Score and Inconsistency of Response, Robert Glaser, Indiana University.—In psychophysical measurement as the discrimination of a stimulus becomes more difficult,

i. e. as an individual's threshold is approached from either direction on the scale of measurement, his responses become less consistent. The threshold (50%) is defined as the point of greatest inconsistency of response. Test items considered as stimuli similar to the stimuli employed in psychophysical measurement may also evoke an increased inconsistency of response as the individual approaches the point where his response changes from "yes" to "no" or from "right" to "wrong."

If test items are considered in this manner certain hypotheses can be developed concerning the relationship between inconsistency of response to test items (as measured by test-retest) and test score. It can be shown that under certain conditions a spurious correlation may result between inconsistency and test score even when it is assumed that no true relationship exists between the two. The analysis throws doubt upon the results of previous studies which report inconsistency as a trait of behavior correlation with intelligence and personality factors.

Validation of Personality Test Results Against Laboratory Behavior. LAWRENCE M. BAKER and JANE S. HARRIS, Purdue University.—The purpose of the experiment was to compare results obtained by the use of the Rorschach Test and the Minnesota Multiphasic Personality Inventory with certain changes in speech performance under normal and stressful conditions. Fourteen subjects were used and several correlations were run. The most significant were the comparisons of form quality and form-color integration with speech intelligibility and variations of voice intensity. Those individuals whose Rorschach record would indicate greatest emotional instability were most disturbed under stress as indicated by a decrement in speech performance. Those subjects having the high Psychosis score on the MMPI test were found to reflect the least indication of disturbance under stress.

Operant Conditioning of a Vegetative Human Organism. PAUL R. FULLER, Indiana University.—In this study a response was conditioned and subsequently extinguished in a so-called "vegetative" human subject. The methods employed were similar to those used by Skinner and others in experiments with rats and pigeons. The subject was the inmate of a feeble-minded institution who had spent his entire nineteen years in a near-vegetative state. His behavior consisted of limited arm movements, opening his mouth, swallowing, blinking, making some vocal noises, and moving his head.

The response conditioned was the elevation of the right arm to a vertical or near-vertical position. The right arm was selected because in a preliminary count it was ascertained that the right arm was elevated only half as frequently as the left. The subject was deprived of food for fourteen hours. The rate of elevation of his right arm was ascertained and considered the base line on which subsequent rates of responding were compared. Thereafter every elevation of the right arm was followed immediately by the injection of several cc. of a sugar and milk solution into the mouth of the subject. With repeated occurence of the response followed by the presentation of the reinforcing stimulus, the rate of response increased until it was more than four times the original rate. When the reinforcing stimulus was no longer presented, the rate of response remained high for a period, then decreased, forming a pattern typical of the extinction curves obtained from infra-human organisms under similar conditions.

A Test for an Assumed Property of the Hypothetical Construct of "Fear": An Attempt to Obtain Conditioned Inhibition of the GSR. H. COPPOCK, Indiana University.—Many experiments in animal learning which have involved electric shock have been interrelated by assuming a motivational factor of fear or tension. This factor is aroused by shock or by stimuli paired therewith, and is reduced by shock termination or by stimuli paired therewith. The reduction of this fear drive is said to constitute reward, which is the strengthening of any preceeding skeletal response.

Stimuli paired with shock termination have been found to become secondary rewards for rats. Presumably such stimuli have become (conditioned) fear reducers. Insofar as fear may be indicated by measurements of the activity of the sympathetic nervous system, as some have asserted that it may be, then these stimuli should have become conditioned inhibitors of sympathetic activity. This was tested with human subjects, using the level of palmar skin resistance as an index of sympathetic activity.

A stimulus (CS) was presented one-half second before the terminations of ten mild shocks of variable duration. Subsequent tests showed that the GSR elicited by this CS was not smaller after than before these trials. The same number of trials was sufficient, however, to condition the CS to the GSR when CS had preceeded the shocks by one-half second.

It is concluded that "fear" is readily conditioned, although fear reduction or tension reduction is not readily, if at all conditionable.

Report of the Remedial Reading Clinic, BLAIR WILSON SPARKS, Butler University.—Students for remedial reading instruction were selected on the basis of their performance on the reading section of the Cooperative English Test which was given to all entering freshman September 16, 1947. All students whose reading scores on this test fell at or below the tenth percentile according to the test norms, were assigned to the reading clinic.

Upon entering the clinic, the students were immediately given the Iowa Silent Reading Test, form DM. This test was administered for diagnostic purposes and was used later in conjunction with form CM of the same test which was given at the end of the instructional period as a means for determining student progress.

Reading instruction consisted, in part, of the use of the Harvard Developmental Reading Program. The program includes fifteen reading films and fifteen equated reading selections. Rate and comprehension scores were selected for each film and reading selection and each student kept a complete record of his achievement on the films and reading selection tests.

The median score attained on the final test was 176.47 whereas the median score on the entering test was 164.56. This shows a gain of 11.80. Furthermore 86.5 percent of the cases exceeded the median on the first test and 68.0 percent of the students on the final test exceeded Q3 of the first test.

The median score attained in the reading rate in September was 260.14 and rose to 497.08 in January. This shows a gain of 239.64. The gain in comprehension accompanying the rise in rate was .55. There were 51.20 percent of the cases which exceeded the September median on comprehension.

Psychology as a Normative Science, CHARLES C. JOSEY, Butler University.—Psychologists have shown considerable interest in what men desire, but have neglected to make serius inquiry into what men should desire. Many confused persons are asking, "What should I do?" Granted that psychologists have no method of discovering the good beyond those available to the thoughtful and observant person, yet it does not seem unreasonable to expect those who specialized in the study of human nature to gain some insight into what constitutes man's highest good. An explanation of why psychologists have neglected this aspect of human nature, and some suggestions for making the needed inquiry are offered.

ZOOLOGY

Chairman: JOHN W. BAECHLE, C.P.P.S., St. Joseph's College

Murven R. Garner, Earlham College, was elected chairman for 1949.

ABSTRACTS

Impedance—Frequency Measurements on Cattle Semen. J. C. HENDRICKS, Franklin College.—Small organisms exhibit electrical polarity while alive and the electric moment has been found in some cases to be a function of the health and virility of the specimen. When large numbers of such organisms are suspended in a solution, the impedance of the suspension should vary with frequency much as it does for a polar liquid. This suggests that the number and virility of the spermatozoa suspended in semen should affect the impedance—frequency relation. Such a relation would be of value as a test for the effectiveness of bulls used in artificial insemination programs.

The conductance cell used consisted of graphite electrodes 2mm apart having a cross sectional area of 5 cm^2. Potential was supplied by an audio or an intermediate frequency oscillator. Potential difference applied to the cell was measured by a vacuum tube voltmeter and the current through the cell by a vacuum thermocouple. The current densities used range from 1 to 20 milliamperes per square centimeter.

It was found that the impedance—frequency curves for semen containing large numbers of active sperms varied markedly in the 20 to 50 kc range from (1) semen containing few live sperms, (2) semen in which the sperm activity was low and (3) semen which had been diluted for insemination purposes. The slope of the curves in this frequency range may prove to be an indicator of the value of the semen for insemination purposes.

INDEX

Acer saccharaphorum, 73.
Adis-Castro, Elias, 47.
Allyn, W. P., 5, 151, 160.
Alcohols, Rapid estimation of, 142.
Alcohols, Sulfur-containing, some p-nitro and aminobenzoates of, 148.
Amino alcohols, Ease of esterification of, 120.
Anox longpipes Hagen (Odonata; Aeshnidae), in Indiana, 151.
Angel Mounds, Casual observation on—skeletal material, 50.
Anthropology, Section on, 47.
App, B. A., 152.
Archeological manifestations of Owen County, Indiana, 53.
Archeologists, Early Hoosier, 252.
Asher, E. J., 15, 290.
Atomic states, Metastable in gas discharge, 288.

Bacteriology, Section on, 55.
Baechle, J. W., 5, 294.
Baker, Lawrence M., 291.
Barton, Thomas Frank, 222.
Beam, vibrating, Determination of deflective curve by means of bonded strain gages, 289.
Behrens, C. A., 263.
Behrens, Otto K., 63.
Bieber, C. L., 244.
Black, Glenn A., 252
Botany, Section on, 69.
Boucher, Raymond, 128.
Brock, James E., 289.
Brodie, H. J., 5, 69, 69.
Brown, Herbert C., 97.
Budde, Walter M., 111.
Burkett, Howard, 142.
Burns, R. E., 99.

Cagle's Mill flood control reservoir, Geological features of, 163.
Campaigne, E., 111, 128, 148.
Campbell, Barbara K., 120.
Campbell, Kenneth N., 120.
Campbell, M.S.A., 5, 55.
Carbon, Distribution of, between zerconium and ferrite phases, 132.
Carr, Arthur B., 5, 47.
Carrot and sunflower roots, growth patterns, 69.
Cassell, R. K., 232.
Chemistry, Section on, 97.
Chemotherapy, Historical landmarks of, 263.
Christy, O. B., 5, 15.
Cities, Indiana, Size, growth, and distribution, 222.
Clauser, Charles E., 49.
Cleland, Ralph E., 71.
Columbus, Indiana, Geographical factors affecting industrial expansion of, 225.
Complexes, Relative stability of Nickel (II), 125.
Condensations of polyamines and polyfunctional compounds, 140.
Conservation of natural resources in Indiana, A brief history of, 257.
Conservation, Soil in action, 208.
Cook, D. J., 145.
Corn borer parasites, Introduction of in Indiana, 157.
Corn embryos, right and left-handed, 69.
Costa Rica, Unsolved anthropological problems of, 49.
Cottingham, John O., 81.
Cross, A. T., 70.
Cucumber industry at Terre Haute, Indiana, 214.
Cyathus stercoreus, 69.

Daily, William A., 5, 15.
Davis, Delmar O., 288.
Degering, Ed. F., 107, 140.
DenUyl, Daniel, 73.
Devonian-Mississippian Flora of Indiana and Kentucky, part I: geological aspects, part II: paleobotanical aspects, 70.
Dialkylaminoalkyl esters of phenoxyacetic acids, 128.
Dock, Darrel, 145.
Dragoo, Don W., 50.

Edington, Will E., 27, 250.
Edwards, P. D., 5, 15.
Electric light and power industry of Indiana, 232.
Ellson, D. G., 5, 290.
Emil Fischer concept, Validity of, 107.
Emotionally-toned situations, Retest of adolescents' interpretation of, 290.

Entomology, Section on, 151.
Ervin, Robert P., 15, 55.
Everly, Ray T., 152.

"Fear", test for an assumed property of· an attempt to obtain conditioned inhibition of GSR, 292.
Ferguson, Philip R., 148.
Ferrite, Distribution of carbon between and zerconium phases, 132.
Fishel, W. P., 132.
Fluorine in waters, Determination of, 98.
Forest control, Versailles park, 72.
Forlaw, Ethyl Shannon, 125.
Fuller, Paul R., 291.
Fungi, Higher of Marion County, Indiana, 81.

Gantz, E. St. C., 5, 15, 97, 98, 99, 125.
Garner, Murvel R., 15, 294.
Geographic regions, Indiana's, 246.
Geologists, Indiana before 1900, 250.
Geology and Geography, Section on, 161.
Girton, Raymond E., 268.
Glaser, Robert, 290.
Grating, Investigations with reflection echelon, 288.
Guernsey, James Lee, 225.

Hagen, C. W., Jr., 69.
Harris, Jane S., 291.
Hayes, John C., 132.
Helman, Vernon, 53.
Hendricks, J. C., 5, 288, 294.
History of Science, Section on, 250.
Hoskins, J. H., 70.
Hudelson cavern, Stormwater route of underground Lost River, 236.
Huff, Dorothea E., 63.
Hufford, Mason E., 5.
Hurlbut, Floy, 5, 161.
Hylastinus obscurus (Marsh), Insecticidal control of the clover root borer, 152.

Inpedence-Frequency measurements on cattle semen, 294.
Incubation temperature, influence of an amount of influenza virus in chorioallantoic fluid of chick embryos, 57.
Indiana plant distribution records, 92.
Inorganic chemistry, undergraduate curriculum, 97.
Insecticidal control of the clover root borer *hylastinus obscurus* (Marsh), 152.
Ives, Ronald L., 196.

Jackson, Glenn A., 137.
James, Harold D., 57.
James, Hubert M., 289.
Josey, Charles C., 293.
Junior Academy—Council members 17, Exhibits 21, Minutes 18, officers 17, program 17.

Kessel, William G., 15, 97.
Kingkade, Mary Jane, 63.
Kintner, Edward, 15, 151.
Koch, G. David, 208.
Koffler, H., 55.

Laubengayer, R. A., 15, 69.
Larvacide for pools and ponds, 160.
Lee, C. O., 250.
Linguistics without meaning and culture without words, 47.
Liquids, Aerating by shaking, 55.
Lithium Hydride, Studies of, 99.
Liverworts, Notes on Indiana I, 76, II Porella, 78.
Long, Alma, 290.
Lost river, Hudelson cavern, a stormwater route of underground, 236.
Lysozme, studies with bacterial virus, 63.

Malott, Clyde A., 236, 250.
Mathematics, Section on, 288.
Marshall, C. Edw., 153.
McClain, John A., 57.
McGrain, Preston, 15, 161, 163, 173.
Meissner, K. W., 288.
Members, New, 1948, 22.
Michaud, H. H., 257.
Miller, Donald E., 5.
Minutes of: Executive committee, 9; General session, 15; Junior Academy, 18; Spring meeting, 7.
Montgomery, B. Elwood, 151.
Morgan, W. P., 5, 9, 15.
Mosses and their Uses, 31.
Mutations, Chemistry of controlled, 137.

Natural resources of Indiana, Brief history of conservation of, 257.
Necrology memorials: Emil Dietz, 27; Charles Tobias Knipp, 27; Gladys Ethelyn Knott, 29; Milton Matter, 30.
Neuman, G. K., 47.
Neutron diffraction by ice crystals, 289.
New Albany shale flora, Status and Correlation of, 161.
Nickel (II), Relative stability of complexes, 125.

O'Boyle, Charles J., 120.
Odonata, The describers of, 151.
Oenothera, 71.
Operant conditioning of a vegetative human organism, 291.
Oriental fruit moth control by spraying, 153.
Overman, Paul, 15, 288.

Parasites, Introduction of, corn borer, in Indiana, 157.
Pearce, D. W., 99.
Personality test results against laboratory behavior, Validation of, 291.
Pharmacy, Second decade of Purdue University's school of, 250.
Phenoxyacetic acids, dialkylaminoalkyl esters of, 128.
Physics, Early in Indiana (to 1900), 253.
Physics, Section on, 288.
Polyamines, Condensations of-and polyfunctional compounds, 140.
Porter, Charles L., 15.
Potzger, J. E., 72.
Presidential address, 31.
Protoplasm, Early studies on, 268.
Psychology as a normative science, 293.
Psychology, Section on, 290.

Quinn, B. E., 289.

Rainfall variability, 196.
Ramsey, R. R., 253.
Reading clinic, Report of the remedial, 293.
Rhesus factor, Recent anthropological data, 49.
Rudd, Robert, 214.
Rulfs, Charles L., 97.

Schick, John W., 140.
Scientists of Indiana sketched in American Men of Science, 251.
Sears, R. W., 145.
Selenium Dioxide, Oxidations with, 145.
Servo theory, Application to human motor behavior, 290.
Settlement in Indiana, Trends indicated by voting residences of officials, 161.
Simmons, Emory G., 82.
Soil conservation in action, 208.
Southern Utes, racial affiliations of, 47.
Sparks, Blair Wilson, 293.
Starkey, Otis P., 206.
Starks, Opal P, 55.
Starred scientists born or trained in Indiana, 274.
Strietelmeier, John, 161.
Stromatic Sphaeriales of Indiana, Studies in, II, 82.
Sugar maple, establishment and growth of seedlings, 73.

Terre Haute Scientific Association, 250.
Test score and inconsistency of response, Prediction of relationship between, 290.
Thomas, Ancil R., 15, 288.
Thrun, W. E., 98.
Trithianes, Structure of stereoisomeric, 111.
Turquoise, More about composition of, 97.

Visher, Stephen S., 5, 15, 246, 250, 251, 274.
Voegelin, C. F., 47.

Wabash Academy of Science, 250.
Wade, Frank B., 97.
Wagner, Kenneth A., 76, 78.
Wallace, William, 15, 47.
Water, Ground resources of Henry County, 173.
Water, Underground and glacial geology of Scottsburg, Indiana, 188.
Weather, Optimum Indiana elsewhere, 206.
Weatherwax, Paul, 5, 15, 250.
Welch, Winona H., 5, 31.
Whitcraft, L. H., 5, 88.
Wickwire, Grant T., 188.
Wilson, M. Curtis, 157.
Wisconsin arch, Structural trends of southern flanks of, 244.

Zoology, Section on, 294.

PROCEEDINGS

of the

Indiana Academy *of* Science

Founded December 29, 1885

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Volume 59

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ALTON A. LINDSEY, EDITOR

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Spring Meeting
May 13 and 14
CLIFTY FALLS

* * *

Fall Meeting
November 3, 4, and 5
WABASH COLLEGE

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TABLE OF CONTENTS

Officers and Committees for 1949 . v
Minutes of the Executive Committee. viii
Minutes of the General Session . . xiii
New Members of the Year 1949 . . xvi
Junior Academy of Science.. xx
Necrology 1
Presidential Address—C. L. Porter . 8

Anthropology

Abstracts of papers not published in full . 17
W. R. Adams: Food animals used by the Indians at the Angel Site 19
Hilda J. Curry: Negative painting of Angel Site and southeastern United States 25
Sanchia Schweinsberger: Bone flutes and whistles found in Ohio Valley sites 28
C. P. Warren: The relationship between the folk-tale and the culture area in Central Africa 34

Bacteriology

Abstracts of papers not published in full 37

Botany

Abstracts of papers not published in full 40
Indiana plant distribution records, X. 1949. . . . 48
William W. Bloom: The Pteridophytes of the Valparaiso Moraine of Porter County, Indiana 53
John O. Cottingham: Higher fungi of Marion County, Indiana 58
Daniel Denuyl: Natural regeneration from planted conifers in Indiana 59
Charles B. Heiser, Jr.: A comparison of the flora as a whole and the weed flora of Indiana as to polyploidy and growth habits 64
John A. Jump: Observations upon a strain of *Streptomyces albus* antagonistic to certain phytopathogenic fungi . 71
J. H. Lefforge: An analysis of floret fertility in *Agropyron repens* 75
M. S. Markle: The Algae of the Edmund Niles Huyck Preserve 80
J. E. Potzger and Leland Chandler: Beech in the forests about Laughery Creek valley 82

J. E. POTZGER and ESTHER POTZGER: Secondary succession in an Illinoian tillplain habitat 95
RICHARD A. SCOTT: A study of variation in leaf anatomy with reference to habitat in two species of *Polypodium* 102
KENNETH A. WAGNER: Notes on Indiana Liverworts—III. Some new county and state records 112
WINONA H. WELCH: Studies in Indiana Bryophytes VII . . 115

Chemistry

Abstracts of papers not published in full 122
ANNE DECKARD and R. C. CORLEY: Utilization of limit dextrins by the animal body 123
ED F. DEGERING and H. H. CHEN: Acetylation with isopropenyl acetate 126
PHILIP J. ELVING and MELVIN L. MOSS: Centering of rotating microscope stages 129
ROBERT B. FISCHER: Academic training in analytical chemistry . 131
C. E. KASLOW, JEROME D. GENZER, and JAMES C. GOODSPEED: Beckmann rearrangement of Oximes of certain quinolyl ketones. . . . 134
W. G. KESSELL: Look it up, freshman 140
F. C. MATHERS and GUY W. LEONARD, JR.: Preparation of fluoboric acid from fluosilicic acid and boric acid, and a comparison of the protective value of electrodeposited lead from fluosilicate and from fluoborate baths 144
S. M. MCCLURE: Achievement in chemistry under the single subject system 147
T. J. PHILLIPS: Rapid analysis of dolomitic limestones . . 149
F. J. RIEL, ED. F. DEGERING, and H. B. HASS: The addition of nitrogen and tetroxide to ketene 150
H. F. SCHAEFFER: Dehydrogenations by means of sulfur: adaptation as an experiment for general organic chemistry course. . . . 153
W. E. THRUN: Modification of the orthotolidine method for determining small amounts of iodine. 155

Entomology

Abstracts of papers not published in full 156
PHILIP W. BERG: Laboratory tests on the toxicity of technical DDT, DDT isomers and analogues, and DDD 157
RAY T. EVERLY: Legume pollination problems 164
GEORGE E. GOULD: The German roach as a laboratory test animal 173
G. EDW. MARSHALL: The control of insects in sod culture peach orchards 181
R. P. MULLETT: The relation of particle size to the toxicity of DDT dusts 185
W. E. RICKER: Some evolutionary trends in Plecoptera . . 197
DONALD L. SCHUDER: Studies on the control of the *Taxus* Mealybug 210

Geology and Geography

Abstracts of papers not published in full . . . 212
THOMAS F. BARTON: Some geographic recreational aspects of unglaciated Indiana . . . 216
C. L. BIEBER: Distribution patterns of sand and gravel pits in northwestern Indiana . . . 221
ERWIN J. BULS: The Grand Portage fur traders route and Indian reservation . . . 225
JAMES L. GUERNSEY: The trade area of Terre Haute, Indiana . . . 230
FRED H. KLAER, JR.: Ground-water levels in Indiana . . . 236
FRANK E. KOTTLOWSKI: A new species of *Atrypa* from the Devonian of Montana . . . 246
E. A. STONEMAN: Commerce of Ireland . . . 251
STEPHEN S. VISHER: Indiana Thunderstorms . . . 255
WILLIAM J. WAYNE: A karst valley in western Monroe County, Indiana . . . 258

Mathematics

Abstracts of papers not published in full . . . 264

Physics

Abstracts of papers not published in full . . . 266
RONALD L. IVES: Preliminary theory of an electrical computer for mean deviations . . . 273

Psychology

Abstracts of papers not published in full . . . 283

Zoology

Abstracts of papers not published in full . . . 291
C. J. SHELLABARGER and W. R. BRENEMAN: The effects of pinealectomy on young White Leghorn Cockerels . . . 299
Instructions for Contributors . . . 303
Index . . . 305

OFFICERS AND COMMITTEES FOR 1949

OFFICERS

President, Charles L. Porter, Purdue University.
Vice-President, Stephen S. Visher, Indiana University.
Secretary, O. B. Christy, Ball State Teachers College.
Treasurer, Will P. Morgan, Indiana Central College.
Editor, E. S. Gantz, Purdue University.
Press Secretary, William A. Daily, Butler University.

DIVISIONAL CHAIRMEN

Anthropology, G. K. Neumann, Indiana University.
Bacteriology, I. C. Gunsalus, Indiana University.
Botany, Dr. A. R. Bechtel, Wabash College.
Chemistry, William G. Kessel, Indiana State Teachers College.
Entomology, Edward Kintner, Manchester College.
Geology and Geography, Preston McGrain, Indiana Flood Control and Water Commission.
History of Science, Paul Weatherwax, Indiana University.
Mathematics, Paul Overman, Purdue University.
Physics, Ancil R. Thomas, Valparaiso University.
Psychology, E. J. Asher, Purdue University.
Zooolgy, Murvel R. Garner, Earlham College.

EXECUTIVE COMMITTEE

(Past Presidents, Current Officers, Divisional Chairmen
and Chairmen of Standing Committees)

William Wallace, Robert F. Ervin, A. R. Bechtel, William G. Kessel, Edward Kintner, Preston McGrain, Paul Weatherwax, Paul Overman, Ancil R. Thomas, E. J. Asher, Murvel R. Garner, C. A. Behrens, O. B. Christy, W. A. Daily, J. J. Davis, C. C. Deam, E. F. Degering, W. E. Edington, H. E. Enders, R. C. Friesner, E. S. Gantz, Theodor Just, Eli Lilly, J. F. Mackell, E. G. Mahin, C. A. Malott, M. S. Markle, M. G. Mellon, H. H. Machard, W. P. Morgan, F. Payne, R. R. Ramsey, F. B. Wade, F. N. Wallace, Winona H. Welch, J. S. Wright, T. G. Yuncker, Stephen S. Visher, Charles L. Porter, K. S. Means, W. E. Ricker, Ralph E. Cleland, Nellie M. Coats, J. E. Switzer, Willis H. Johnson.

BUDGET COMMITTEE

(President, Secretary, Treasurer, Editor and Chairman of Junior Academy, Library, Program, and Relation of Academy to State)

Charles L. Porter, Purdue University; O. B. Christy, W. P. Morgan, E. S. Gantz, H. H. Michaud, Nellie M. Coats, W. H. Johnson.

COMMITTEES

(Elected by the Academy)

Trustees of Academy Foundation (Term 4 years): Chairman, J. S. Wright, Eli Lilly and Co., Indianapolis (term ex. 1952); F. B. Wade (term ex. 1951).

Bonding of Trustees (elected annually): Chairman, R. C. Friesner, Butler University; Scott McCoy.

Research Grants (term 5 years): Chairman, T. G. Yuncker, DePauw University (term ex. 1949), E. G. Mahin (1952), H. H. Remmers (1950), Paul Weatherwax (1951), J. S. Wright (1953), Charles L. Porter and O. B. Christy (ex. officio).

COMMITTEES APPOINTED BY THE PRESIDENT

Auditing: Chairman, K. S. Means, Butler University; S. E. Elliott.

Biological Survey: Chairman, W. E. Ricker, Indiana University; W. P. Allyn, W. B. Barnes, H. J. Bródie, L. C. Cole, Fay K. Daily, H. O. Deay, R. C. Friesner, H. H. Michaud, H. H. Vogel, Winona H. Welch.

Fifty-Year Index: Chairman, R. C. Friesner, Butler University; Nellie M. Coats, W. P. Morgan, F. N. Wallace, Paul Weatherwax.

Invitations: Chairman, Professor Ralph E. Cleland, Indiana University; John S. Karling, Edward Kintner, Fred A. Loew, Edna Banta, Floyd Beghtel.

Junior Academy: Chairman, H. H. Michaud, Purdue University; N. E. Adams, W. P. Allyn, F. R. Elliott, E. Kintner, M. S. Markle, R. Earl Martin, A. Strickler, F. B. Wade, P. L. Whitaker.

Indiana Science Talent Search: A sub-committee of the Junior Academy Committee—Chairman, R. W. Lefler, Purdue University; F. Payne, P. D. Edwards, Winona H. Welch, Lawrence H. Baldinger, Charles L. Porter, and Walter Leckrone (ex officio).

Library: Chairman, Nellie M. Coats, Indiana State Library, Indianapolis; W. G. Gingery, R. C. Friesner.

Membership: Chairman, J. E. Switzer, Indiana University; M. H. Ahrendt, Juna L. Beal, E. Byren, Jr., M. Chanin, J. J. Davis, S. R. Esten, G. F. Hennion, L. B. Howell, J. L. Hyatt, Alma Long, J. A. Marling, A. H. Meyer, Bessie Noyes, A. E. Reynolds, J. E. Seybert, W. Shepherdson.

Necrologist: W. E. Edington, DePauw University.

Nominations: (Announced at the November meeting of the Academy).

Program: Chairman, Willis H. Johnson, Wabash College; A. R. Bechtel, Crawford Polley, R. E. Martin, L. B. Howell, John E. Potzger, Scott McCoy, Alton A. Lindsey.

Publication of Proceedings: Chairman, E. S. Gantz, Purdue University; R. C. Corley, Paul Weatherwax, P. D. Edwards.

Relation of Academy to State: Chairman, F. N. Wallace, Department of Conservation; H. J. Reed, Eli Lilly, J. S. Wright, Daniel Den Uyl.

Representative on Council of A.A.A.S.: Paul Weatherwax, Indiana University.

Resolutions: Chairman, Stephen Visher, Indiana University; Arthur T. Guard, Howard Ray Youse.

MINUTES OF THE EXECUTIVE COMMITTEE

CRAWFORDSVILLE, NOVEMBER 3, 1949

The executive committee was called to order by C. L. Porter in the Library Building at 7:30 p. m. The minutes of the spring meeting held at Clifty Falls State Park were read and approved. The report of the officers and committee representatives were presented and accepted as follows:

Academy Trustees. John S. Wright, chairman of the Trustees of the Foundation Fund, reported as follows for the year 1948-49:

Balance from the Previous Year	$375.01
Total Receipts	165.75
Total	$540.76
Expenditures:	
The Union Trust Co., fee 5% on $165.75	$8.29
Cash Balance at the Union Trust Co.	$532.47

Assets in the Fund as of September 30, 1949

(5)	$1,000.00 U. S. Savings Bonds Series "D"—Cost	$3,750.00
	$6,900.00 U. S. Treasury Bonds Series "G"—Cost	6,900.00
(6)	Shares Standard Oil of Indiana common stock Par	150.00
	Total at Par or Cost	$10,800.00

Treasurer. Final report of the treasurer, W. P. Morgan, for the year 1949:

Receipts

Balance on hand January 1, 1949	$1,950.17	
Dues and initiation fees	1,189.00	
Designated gifts	450.00	
Publications sold	49.12	
Authors' reprints Vol. No. 54	3.22	
Authors' reprints Vol. No. 57	358.44	
Authors' reprints Vol. No. 58	299.70	
		$4,299.65

Disbursements

1—Program Committee	$ 304.83
2—Editor Vol. No. 58	125.86
3—Expenses of Secretary	224.36
4—Expenses of Treasurer	106.50
5—Mailing Proceedings	136.28
6—Stationery	69.73
7—Publications for Library	20.00
8—Preparation of 10-Year Index	4.98
9—Bookwalter Co., balance on Vol. No. 58	119.83
10—Jr. Academy expenses	20.72
11—Authors' reprints Vol. No. 58	699.29

12—Author award 1949 Tom Daggy	25.00		
13—Author award 1949 Helen Marsh Zeiner	25.00		
14—C. P. Hickman research grant	37.50		
15—A. E Reynolds research grant	18.75		
16—Returned checks	5.06		
17—Expenses to five officers as directed by action of 1947 Executive Committee	100.00		
18—S S. Visher*	300.00		
		$2,343.69	
**Balance on hand		1,955.96	
			$4,299.65

* Drawn for use in preparation of material for "Indiana Men of Science" shown in 1949 records due to delay in closing accounts of that year.

** Balance includes $800.00 designated for the preparation for publication of the "Indiana Men of Science."

(Signed) W. P. MORGAN, *Treasurer.*

(Signed) KARL S. MEANS, S. E. ELLIOTT, *Auditors.*

Auditing Committee. The treasurer's report was audited and approved by the committee. The Statement of the Union Trust Company as to the Society's account and holdings was checked by the trustees and the chairman of the auditing committee.

(Signed) KARL S. MEANS, *Chairman.*

Bonding Committee. Ray C. Friesner, Chairman, reported that the Academy carries with Hartford Accident and Indemnity Company a bond in the amount of $2000.00 for the Treasurer and $5000.00 each for the Trustees. These are on a position basis. The bond is renewable triannually at a total cost of $62.50 for the three-year period. The next expiration date is November 18, 1950, and the bond will be renewed on or before that time unless the Academy should instruct the committee otherwise.

Editor and Publication of Proceedings. In the absence of E. S. Gantz no report was made by this committee. However, Dr. Friesner reported that he had ordered the reprints needed by the State Floral Committee which would amount to about $15. A motion was carried that the Academy bear this expense.

Research Grant. Dr. T. G. Yuncker reported that no requests for grants have been received by the Committee during the past year. Grants made previously to Prof. Drummond of Indiana State Teachers' College, Prof. Hickman of DePauw University, Prof. Reynolds of DePauw University, and Prof. Thrun of Valparaiso University have been continued during the year and installments paid as progress reports were received and approved by the Committee.

Biological Survey. W. E. Ricker reported activities in faunistic and floristic studies continues along much the same lines as reported last year. Drs. L. C. Cole and H. H. Vogel, being no longer resident in Indiana, have asked to be relieved of their position upon the Committee.

Ten-Year Index. Chairman Friesner made the following report:

1. Indexing of volumes 51-58 is complete and has yielded about 8500 entries.
2. Printing cost of 10-year index will be approximately $600.
3. It is recommended that the index for volumes 51-60 be bound in volume 61.
4. Volumes containing 10-year indexes should be bound in red cloth instead of the usual black.
5. Format should be the same as for the 50-year index.

Library. Chairman Nellie M. Coats reported that a revision of the 1935 list has been prepared for distribution at the 1949 fall meeting. This 1949 edition records five hundred one titles, a gain of two hundred seventy. This fiscal year the State Library as agent has mailed copies of two issues of the Proceedings, v. 57 published Dec. 2, 1948 and v. 58 published Oct. 29, 1949, the latter having just been posted to nine hundred six members.

Press Secretary. Dr. W. A. Daily reported news items concerning the meetings of the Academy has been presented to the journal "Science", Indianapolis newspapers and "Newsweek". Printed announcements suitable for posting were sent out to all the colleges and universities in the state. All of the high schools that have had at any time a chapter of the Junior Academy also received a notice. The archives of the Academy are in good condition and a complete series of presidential photographs are on file. Mr. Charles C. Deam of Bluffton has presented to the State Library the major part of his scientific correspondence which covers a period of nearly fifty years.

Junior Academy of Science. Howard H. Michaud, Chairman, presented the following report. There are at present twenty-six active Junior Academy of Science Clubs representing twenty-three Indiana high schools. Two new clubs were added beginning with this school year. An excellent news-letter of club activities was prepared and distributed again last year. A more genuine interest in the Junior Academy and science clubs has been stimulated through the Indiana State Science Talent Search. This is a cooperative effort between the Indiana Junior Academy of Science, Science Clubs of America and the Indianapolis Times. The renewed interest of the clubs is very encouraging and surely proves the value of working with our future potential scientists. An excellent program has been prepared for Saturday's meeting.

Indiana Science Talent Search Committee. Ralph W. Lefler, chairman, explained the work of his committee in setting up rules and regulations for the Senior Science students of Indiana in competing for the awards offered by the Indianapolis Times. This was an excellent report and was accepted with thanks. In addition, Dr. Lefler presented the following on the relation of Indiana colleges to the Science Talent Search:

> The necessity for the early identification and for the continued development of our talented in all fields has long been recognized. In the field of science there have been programs both local and national in scope which tended to encourage the more talented to strive for some reward, usually a scholarship. The Science Talent Search conducted by Science Service for the Westinghouse Scholarships is one of the most outstanding of such attempts.
>
> This Search with the concurrent fifteen state searches brings untold encouragement to all who participate. There are each year 40 National Winners and 360 National Honorable Mentions. In addition 294 students were honored last year in the 15 state searches. 20 of these were from Indiana.
>
> The rigorous selection procedure which requires an essay on an original project and the completion of a three hour Science Aptitude Examination is a maturing and desirable experience for any serious minded high school senior.
>
> All Indiana Winners are recommended to the admissions officers and scholarship committees of our Indiana colleges and universities. It is sincerely hoped that no really talented student will have to terminate his program of education because of inability to bear the financial obligation.
>
> The attendance of Indiana Scientists at the Junior Scientists Assembly held each spring as the culminating activity of the Indiana Science Talent Search will make possible personal interviews with these students and provide opportunity for appropriate encouragement in the field best suited for their continued study.

Relations of Academy to State. Frank N. Wallace, chairman, reported that there has been no change in the status of the state appropriations for the Indiana Academy of Science. There are $3000.00 available this year for the publication of the proceedings. "I checked with the auditor, and so far there has been no commitment made on this, so the entire $3000 is available for this year's publications."

Relation of Academy to A.A.A.S. E. F. Degering reported that he had attended the A.A.A.S. in Washington, but found few representatives from Indiana.

Nominating. C. A. Behrens reported that his committee is recommending the following members for fellows: W. A. Daily, Eli Lilly and Butler University; R. W. Lefler, Purdue University; Preston McGrain, U. S. Flood Control; Daniel Den Uyl, Purdue University; L. H. Baldinger, Notre Dame University.

Program. W. H. Johnson reported that some sectional meetings would be long. The program would proceed as scheduled.

New **Business.** It was moved and carried that Dr. T. G. Yuncker be re-elected as a member to the Research Grants Committee. The members of the present bonding committee were unanimously re-elected for another year.

Dr. W. E. Edington, chairman of the committee on "Indiana Men of Science", recommended that the committee be discharged and a new committee on arranging for compiling and publication be appointed as suggested in a Resolution to be presented at this meeting by Dr. John S. Wright. Dr. Wright presented the following resolutions:

WHEREAS: Scientific activities in Indiana began over a century ago and include significant contributions to the advancement of science, the Indiana Academy of Science believes it desirable and in furtherance of scientific and educational interests to prepare an historical account of science in our state, including biographical records of the men and women of science, past and present, who originated, studied or worked in Indiana, and to do this as speedily as consistent with sound procedure, be it

RESOLVED:

(1) That the president be authorized to appoint a committee of two or more members to study the ways and means for preparing the text for and the publication of such a history.

(2) That the committee be empowered to add to its membership if it so desires.

(3) That the committee be allowed an amount not exceeding four hundred (400) dollars for the first year's work, to be paid out of the treasury's "designated fund," contributed for special publication projects.

(4) That the committee report at the next annual meeting with recommendations for further procedure.

The resolutions were unanimously adopted. President Porter announced that he would appoint a committee.

Dr. R. E. Martin issued an invitation for the Academy to hold its next annual meeting at Hanover College.

The problem of raising the dues was raised and discussed at length. Dr. Friesner then moved that the chair appoint a committee to study the problem of dues and report its recommendation at the next annual meeting. The motion carried and President Porter appointed the following committee: R. C. Friesner, W. E. Edington, Howard Michaud, W. P. Morgan (ex officio).

The meeting adjourned at 9:30 p. m.

MINUTES OF THE GENERAL SESSION

CRAWFORDSVILLE, NOVEMBER 4, 1949

President Frank H. Sparks of Wabash College expressed his appreciation for having the Academy as guest of the college at its sixty-fifth meeting. The response to the welcome was given by President C. L. Porter.

The minutes of the Executive Committee meeting was read by the secretary and approved by the Academy.

President Porter appointed W. E. Edington, J. S. Wright, S. S. Visher, M. G. Mellon and Paul Weatherwax as a committee on the History of Science in Indiana as provided in the resolutions presented by John S. Wright at the executive committee meeting.

Dr. Will E. Edington, chairman of the Necrology committee, presented the list of those members who had died during the year. The names presented were: Benjamin H. Grove, Carl F. Hanske, Thomas F. Hargitt, G. Donald Klopp, and David A. Rothrock.

Dr. Harry J. Fuller, University of Illinois, presented an interesting illustrated talk on "Ancient and Modern Life in the Andes Mountains". The primitive methods used by the people in this region of South America and the ancient ruins were very impressive.

Duane Roller, Wabash College, read a well prepared paper entitled "Some Difficulties in Interpreting Basic Factors in the Relations of the Sciences to Society". The author expressed the Marxist attitude which regards science solely as a social instrument had reached what seems to be an incompatible conflict with the idea of freedom for "pure" scientific research.

C. M. Palmer, Butler University, gave an illustrated talk "The U.N.E.S.C.O. Science Office of South Asia". Dr. Palmer had spent two years in India as a representative of the Friends helping to improve methods in agriculture.

The meeting adjourned at 11 a.m. to meet in the various sections.

Luncheon was served in the Crawfordsville Armory with 345 present.

At the annual dinner in the Masonic Temple the Wabash College male quartet sang several appropriate numbers.

H. B. Howell presented the names of 107 applicants for membership. These were duly elected.

Prof. C. A. Behrens of the nominating committee presented the following names for fellows: W. A. Daily, Eli Lilly Co.; L. H. Baldinger, Notre Dame; R. W. Lefler, Purdue University; Preston McGrain, Indiana Flood Control and Water Resources Commission, Indiana; Daniel Den Uyl, Purdue University. These persons were unanimously elected.

The Divisional Chairmen who were elected to serve the various sections for 1950 were as follows: Anthropology, Harold E. Driver, Indiana University; Bacteriology, H. Koffler, Purdue University; Botany, M. S. Markle, Earlham; Chemistry, Kieth Seymour, Butler University; Entomology, George Gould, Purdue University; Geology and Geography, Otis P. Starkey, Indiana University; History of Science, M. G. Mellon, Purdue University; Mathematics, Walter H. Carnahan, Purdue University; Physics, Duane Roller, Wabash College; Psychology, Robert Bruce, Wabash College; Zoology, Sears Crowell, Indiana University.

P. D. Edwards reported for the awards committee as follows:

> The fields of science selected for 1949 are anthropology and entomology. The Eli Lilly prize in anthropology is awarded to Mrs. Helen Marsh Zeiner of Denver, Colorado, for her paper entitled "Botanical Survey of the Angel Mounds" which appeared in Vol. 54. The J. J. Davis prize in entomology is awarded to Tom Daggy of Olivet College, Olivet, Michigan for his paper entitled, "Notes on the ecology and taxonomy of certain pupae of the family Tenebrionidae (Coleoptera)" which appeared in Vol. 56.

C. A. Behrens of the nominating committee recommended the following persons for the 1950 officers:

President	S. S. Visher, Indiana University
Vice-President	O. B. Christy, Ball State
Editor	A. A. Lindsey, Purdue University
Secretary	W. A. Daily, Eli Lilly Co.
Treasurer	W. P. Morgan, Indiana Central College
Press Secretary	Preston McGrain, Indiana Flood Control

This recommendation was approved and the officers unanimously elected.

An invitation to meet at Hanover College in 1950 was accepted.

Dr. S. S. Visher, chairman of the resolutions committee, read the following report:

> The Academy expresses appreciation to the Program Committee, chairman Willis H. Johnson, A. R. Bechtel, L. B. Howell, Alton A. Lindsey, R. E. Martin, Scott McCoy, Crawford Polley, and John E. Potzger for their earnest efforts to make this meeting the success it has been.
>
> The arranging for places of meeting of the various sections, committees and the entire academy and for the meals and lodging is a far larger job than those who have never done it realize. The Academy is under special obligation to Chairman Willis Johnson for much devoted service.
>
> To Wabash College, we are grateful for kind hospitality. Everytime that the Academy meets here, we have increased reason to appreciate this splendid college, which has for many decades contributed much to the educational life of Indiana.
>
> The Academy also expresses appreciation for the devoted services of O. B. Christy as secretary, who after several years of service finds it necessary to retire.

Vice-President S. S. Visher presented President C. L. Porter who read an excellent paper on "Responsibilities of a Mycologist," The Sixty-Fifth Annual Meeting of the Indiana Academy of Science with 430 registrants, 345 attending the luncheon, and 177 the dinner, was adjourned.

O. B. CHRISTY, Secretary.

NEW MEMBERS OF THE YEAR 1949, INDIANA ACADEMY

Alexander, Raymond L., 5020 E. Iowa St., Indianapolis. B
Anthonisen, Robert P., 8011 S. Muskegon Ave., Chicago 17, Ill. G, Geo

Beecher, A. B., Journal-Review Office, Crawfordsville. B
Blackburn, Jack B., 224 Waldron St., W. Lafayette. Highway Engr
Blasingham, Miss Emily Jane, Anthropology Museum, Indiana Univ., Bloomington. A
Blumenthal, Harold Jay, Dept. of Biological Sciences, Purdue Univ., Lafayette. Ba
Bohman, Frank E., 46 Newport Ave., W. Hartford 7, Conn. E
Boling, Richard C., 2830 Brookside Ave., Indianapolis. Z
Buck, Dr. Miriam G., 798 N. Walnut St., Franklin. C
Buser, Franklin B., D-20 Woodlawn Courts, Bloomington. Bo
Buss, Arnold H., Psychology Dept., Indiana Univ., Bloomington. Psych

Canright, Dr. James E., 1604 E. University St., Bloomington. Bo
Carpenter, T. R., Dept. Bot. and Pl. Path. A.E.S., Purdue Univ., W. Lafayette. Pl Path
Chamberlin, Miss Lois, Dept. of Botany, Purdue Univ., W. Lafayette. Bo
Clemmons, George E., 6811 Anthony Ave., Chicago, Ill. G, Geo
Coulter, Miss Kathryn E., 211 S. 12th St., Richmond. B
Crandall, Richard B., 611 Ridge Ave., Greencastle. Z
Crawford, Dr. Wiley W., 635 S. Englewood Drive, Evansville. B, Z
Cummings, Robert H., 432 N. Grant St., W. Lafayette. Mycol
Curry, Miss Hilda J., Route 6, Bloomington. A

Davis, Hugh N., Jr., 624 N. Drexel Ave., Indianapolis. A
Day, Richard E., Dept. of Biology, Purdue Univ., W. Lafayette. Mycol
Daykin, P. N., Dept. Physics, Purdue Univ., W. Lafayette. P
Deckard, Mrs. Anne DeBoer, 314 W. Fowler St., W. Lafayette. C
DeLanney, Dr. Louis E., 900 S. Grant Ave., Crawfordsville. Z
Dillingham, Elwood Oliver, Florence Hall, Greencastle. Ba
Driver, Dr. Harold E., Anthropology Dept., Indiana Univ., Bloomington. A
Ducommun, Dale J., Sigma Nu House, Greencastle. Z, Psych

Eliason, Miss Alma E., Richmond Sr. High School, Richmond. B

Fiandt, Dallas, Jr., Hoosier Court Apts., Bldg. 29, Apt. 3, Bloomington. G
Finnegan, Cyril V., Wabash College, Crawfordsville. Z, Embry
French, Richard C., Dept. Biological Sciences, Purdue Univ., W. Lafayette. Pl Physio
Fry, Prof. Cleota G., 213 Varsity Apt., W. Lafayette. M

Geyer, Prof. J. Hubert, 38 S. Edwards St., Franklin. Z
Gorsline, William W., 923 E. 56th St., Indianapolis. M
Gould, Dr. S. H., 117 DeHart St., W. Lafayette. M
Grassi, Gino V., 958 Bridge Ave., Windsor, Ontario, Canada. B
Green, Ralph J., Jr., 1835 S. 31st St., Terre Haute. Bo
Greenspoon, Joel, Psychology Dept., Science Hall, Indiana Univ., Bloomington. Psych

Haenisch, Prof. Edward L., 309 S. Walnut St., Crawfordsville. C
Hammond, Phillip V., School of Pharmacy, Purdue Univ., W. Lafayette. Pharm
Harcourt, Robert S., 4915 N. Illinois St., Indianapolis. Z
Haxby, Dr. R. O., Dept. Physics, Purdue Univ., W. Lafayette. P
Hennigar, Prof. Lewis Albro, Anderson College, Anderson. Psych
Hilliker, Eugene F., Shortridge High School, Indianapolis.
Hoffman, Max Norman, Route 2, Cory. B, C
Hovorka, Edward J., 314 E. 6th St., Bloomington. Psych
Hughes, Dr. Howard K., 617 Dodge St., W. Lafayette. M
Huse, Erle S., Hanover College, Hanover. C
Hurst, Mrs. Fannie Mae, Dept. of Biology, Purdue Univ., W. Lafayette. Bo

Johnson, Miss Laveta Audrey, 4315 Cold Spring Rd., Indianapolis.
Johnson, Dr. Vivian A., Dept. Physics, Purdue Univ., W. Lafayette. P
Judson, Dr. James Edward, 286 Forsythe St., Franklin. Ba, Bo

King, Roger F., 524 N. Jefferson St., Madison. Ba, Myco

LaCroix, J. Donald, Purdue Univ., W. Lafayette. Bo
LaTourrette, Miss Eleanor J., 309 E. 3rd St., Bloomington.
Lefforge, Prof. Jesse H., 434 N. Grant St., W. Lafayette. Bo, Agro
Lehman, Eldon D., 664 E. 17th St., Apt. 4, Indianapolis. C
Lewis, Robert Owen, 311 3rd St., Carmi, Ill. Z
Livesey, Dr. Robert L., Univ. of Notre Dame, Notre Dame. B
Luck, John Virgil, Purdue Univ., W. Lafayette. Ba, My

Maatman, Prof. Russell W., Chem. Dept. DePauw Univ., Greencastle. C
Mann, David Edwin, Jr., 142 Sheetz St., W. Lafayette. B
Maysilles, Prof. James H., Dept. Botany, Hanover College, Hanover. Bo
Meinerding, William L., Quonset No. 1, 200 Olive St., Greencastle. Z
Mindach, Fred Carl, 951 W. 20th St., Box 855, Indianapolis. Bo, Ba
Mockford, Edward L., 4140 Graceland Ave., Indianapolis. Z
Mullett, R. P., 663 King Ave., Marion Ohio. E

Nichols, Kenneth E., Valparaiso Univ., Valparaiso. B

Opp, Edward D., Purdue Univ., W. Lafayette. Bo
Ort, Robert Stanley, Psych. Dept., Wabash College, Crawfordsville. Psy
Overmyer, Robert, 10001 S. Hoyne Ave., Chicago 43, Ill. P

Perrey, Joseph I., 522 Board of Trade Bldg., Indianapolis. G, Geog
Peterson, Dr. J. B., 633 Russell St., W. Lafayette. Agro

Pierard, Louis H., P.O. Box 461, 3d Observation Ct., Greencastle. G
Powelson, Prof. Dorothy M., Dept. of Biological Sciences, Purdue Univ., W. Lafayette. B
Punke, Miss Helen, Evansville College, Evansville. B
Pursell, Lyle E., Route 3, Paola, Kans. M

Quinn, Miss Charlene M., 407 Howard St., Greencastle. Z

Reddix, Lloyd E., Indiana Central College, Indianapolis. P
Rice, Michael W., 215 Longden Hall, Greencastle. P
Rieke, Dr. Foster F., Dept. Physics, Purdue Univ., W. Lafayette. P
Roberts, Carroll N., Dept. of Geology, Indiana Univ., Bloomington. G
Rohrer, Charles St., Chem. Dept. Indiana Univ., Bloomington. C
Rueve, Rev. Charles R., St. Joseph College, Collegeville. M

Schipper, Dr. Arthur L., Univ. of Notre Dame, Notre Dame. B
Schneller, Miss Myrtle V., Dept of Zoology, Ind. Univ., Bloomington.
Schuder, Donald L., Dept. of Ento. A.E.S. Annex, Purdue Univ., W. Lafayette. E
Seifert, Dr. R. L., Dept. Chem., Indiana Univ., Bloomington. C
Simpson, Ralph S., 248 W. 44th St., Indianapolis. C
Sipple, Guy C., Bldg. 11, Apt. 7, Ross-Ade Dr., W. Lafayette. M, P
Smith, Prof. Howard W., Dept. Entomology, Purdue Univ., W. Lafayette. E
Spencer, Dr. Joseph Nuten, 2141 S. 7th St., Terre Haute. Phy, Phar
Springer, Clifford H., 333 W. Sherwood Terrace, Ft. Wayne 6. M
Stark, Ralph W., 122 S. Lebanon St., Lebanon. Bo
Stark, William Max, Stanley Coulter Hall, Purdue Univ., W. Lafayette. Ba
Stearns, Forest, 515-3 FPHA, W. Lafayette. Bo
Stuntz, Edgar Cheadle, Sigma Chi House, Crawfordsville. Psy
Sybil, Dr. Edward, Jr., Dept. of Biology, Univ. of Notre Dame, Notre Dame. Bo

Thevathasan, Oliver, Florence Hall, Greencastle. Z
Trabant, Prof. E. A., 215 Forest Hills Dr., W. Lafayette. M
Treece, Prof. Walter A., Apt. 12-B, 500 S. Rotherwood, Evansville. Geog

Uhrhan, Miss Jane A., 3005 Broadway, Indianapolis. M

Walerstein, Dr. I., 1334 Vine St., W. Lafayette. P
Warner, Dr. Glen W., Lakeville.
Webster, Dr. J. Dan., Hanover College, Hanover. Z
Whaley, Dr. R. M., 19 David Ross Rd., W. Lafayette. P
Willis, Myron J., State St., Ct. B No. 30, W. Lafayette. M
Woods, Prof. Kenneth B., 902 N. Chauncey Ave., W. Lafayette. Geog

Young, Charles Edward, FPHA 318-3, W. State St., W. Lafayette. M, P
Young, Dr. Frank N., Jr., Dept. of Zoology, Indiana Univ., Bloomington.

Zieman, Dr. Clayton, 314½ W. Main, Crawfordsville. P

JUNIOR ACADEMIES

Science Club of Senior High School, Whitewater Bldg., Richmond. P, C, B

Science Club, Huntingburg High School, Wilmer K. Pellett, sponsor, Huntingburg. G. S

Morton Science Club, 7040 Marshall Ave., Hammond
Photography, area of biological sciences

INDIANA JUNIOR ACADEMY OF SCIENCE

Officers for 1949:

President: RICHARD ELZAY, Phi Chem Club, Elmhurst High School, Fort Wayne.

Vice-President: Tom Moon, Junior Academy, Central High School, South Bend.

Secretary: MARJORIE TAPSCOTT, Biology Club, New Castle Senior High School, New Castle.

PROGRAM OF THE SEVENTEENTH ANNUAL MEETING

Saturday, November 5, 1949

Waugh Hall, Wabash College, Crawfordsville, Indiana

9:00-10:00 A.M. Exhibits, Room 101, Waugh Hall

10:00 A.M. Morning Session, Room 1, Waugh Hall

Richard Elzay, presiding.

Greetings, Dean B. K. Trippet, Wabash College.

Program presented by club members:

1. Plastic Microscope Slides—Kay Boese, Nature Study Club, Arsenal Technical High School, Indianapolis.
2. Hybridizing Roses at Hill's Greenhouse—Robert Milligan, Science Club, Richmond High School, Richmond.
3. Rabbit Royalty—Mary Martha Curd, Nature Study Club, Arsenal Technical High School, Indianapolis.
4. Bird Population Study (Illustrated)—Marjorie Tapscott, Biology Club, New Castle Senior High School, New Castle.
5. Interesting Facts About Astronomy—Robert Usher, Biology Club, New Castle Senior High School, New Castle.
6. The Water Problem of South Bend—Tom Moon, Junior Academy, Central High School, South Bend.
7. Gems of the Ocean—Mary Jane Patrizi, Biology Club, Lew Wallace High School, Gary.
8. Demonstration—Vandegraff Generator—Tom Miller and John Goodman, Science Club, Mishawaka High School, Mishawaka.

9. Bird Adaptations—Judith Douthitt, National Scientific Honor Society, Bloomington High School, Bloomington.

10. What Will a Frog Heart Do? (Demonstration)—Tao Yuan Chen, Chemistry Club, Shortridge High School, Indianapolis.

12:30 P.M. Junior Academy Luncheon

First Baptist Church

Miss Audrey Johnson, Scientific Honorary Student, Purdue University, and one of the last year's National Science Talent Search Winners will speak on "Experiences as a National Winner in Washington, D.C."

1:45 P.M. Room 1, Waugh Hall

11. How to Make a Bird Identification Board—Bill Zander, Biology Club, Lew Wallace High School, Gary.

12. Destruction of Wildlife on Our Highways—Kelly Wise, Biology Club, New Castle Senior High School, New Castle.

13. Out of the Past (Illustrated)—Bill Luckey, Junior Academy, Elkhart High School, Elkhart.

14. Somatotyping—Jim Heuston, Science Club, Howe High School, Indianapolis.

15. Geology Field Trip—Vivian Shilling, Chemistry Club, Shortridge High School, Indianapolis.

16. Additional Investigations of a High Frequency Oscillator—Charlie Bob Ellis, University High School, Bloomington.

17. Pathogenic Mold—Watson Laetsch, Science Club, Howe High School, Indianapolis.

MINUTES

The seventeenth annual meeting of the Indiana Junior Academy of Science was held Saturday, November 5, 1949, in room 1 of Waugh Hall, Wabash College, Crawfordsville, Indiana.

The exhibit room opened at 9:00 a.m. Exhibits and demonstrations were displayed by a number of individuals and clubs.

The general session was opened by President Richard Elzay, Phi Chem Club, Elmhurst High School, Fort Wayne. Tom Moon, Jr., Academy, Central High School, South Bend, and Marjorie Tapscott, Biology Club, New Castle High School, were introduced as vice president and secretary, respectively. Following these introductions, the president welcomed the new clubs. These new members of the Junior Academy are Richmond, Hammond, and Huntingburg High Schools. Due to a shortage of the time, the officers dispensed with the reading of the previous year's minutes. Next Dean B. K. Trippet, Wabash College, welcomed the Junior Academy of Science and told of the contributions to science made by Wabash College. Mr. David Wells, sponsor of the Crawfordsville High School Science Club, announced plans for the luncheon to be held in the First Baptist Church. Then the president introduced Professor Howard H. Michaud, State Sponsor, who conducted a short memorial service in honor of G. Donald Klopp. Mr. Klopp, a member of the Junior Academy Council, died on May 30, 1949.

Kay Boese, Nature Study Club, Arsenal Technical High School, Indianapolis, opened the morning program with a talk on plastic microscope slides. She discussed the various methods of preparation and the advantages of using plastic microscope slides.

"Hybridizing Roses at Hill's Greenhouse" was the topic presented by Robert Milligan, Richmond Senior High School Science Club. After reviewing the reproductive parts of the flower, he took roses and demonstrated methods used in hybridizing plants. Several real roses were shown as good examples of flowers produced through hybridization.

Another representative from Arsenal Technical High School's Nature Study Club gave a talk on "Rabbit Royalty." Mary Martha Curd discussed the histories of our domestic rabbits and showed their present day importance in the study of medicine and genetics.

Marjorie Tapscott of the New Castle High School Biology Club gave a report of a beech-maple woods. A colored movie was shown to illustrate the methods used in making a bird population study.

Robert Usher, also of the New Castle High School Biology Club, gave a talk entitled, "Interesting Facts About Astronomy." He explained some of the ancient beliefs about the solar system and how they compare with present day scientific knowledge.

The water problem of South Bend was presented by Tom Moon, South Bend Central High School. After discussing ways of obtaining and purifying water, he mentioned the methods used in testing water.

Using her own shell collection as an example, Mary Jane Patrizi, Biology Club, Lew Wallace High School, Gary, demonstrated how shells can be used in making jewelry.

Two boys from the Science Club of Mishawaka High School demonstrated their home-made Vandegraff Generator. Tom Miller and John Goodman told how the generator was made and how it performs. They expressed a desire to make a new, improved generator in the future.

Next Judith Douthitt, Bloomington High School Scientific Honor Society, presented colored bird slides she had made. While showing the slides, she discussed the various characteristics of several common birds found in Indiana.

The last talk scheduled for the morning session was given by Tao Yuan Chen, Chemistry Club, Shortridge, Indianapolis. In searching for the ideal cardiac drug, he has experimented with a number of drugs. Using live frogs he demonstrated the actual effect of various drugs on the heart beat of the frog. Since the audience could see the heart beats being traced on a kymograph, they were able to understand the variation caused by the different drugs.

At the close of the morning program, President Richard Elzay conducted the election of officers for the coming year. The following students were elected: President: Tom Moon, Junior Academy, South Bend Central High School; Vice President: Sue Schaffner, Chemistry Club, Shortridge High School, Indianapolis; Secretary: Marilyn Beckett, New Castle High School Biology Club.

Professor Howard Michaud closed the meeting with an announcement concerning the new council members. He stated that Mr. Harold Stewart, Bloomington High School, and Mr. A. L. Smith, South Bend Central High School, were to be added to the council.

The morning session was closed at 12:30 p.m. A number of Junior Academy members and sponsors attended the Junior Academy luncheon held at the First Baptist Church in Crawfordsville.

At the luncheon Dr. R. W. Lefler from Purdue gave a brief explanation of the Science Talent Search plans for this year. He then introduced Miss Audrey Johnson, Purdue University, who related her experiences in Washington, D. C. as a Science Talent Search Winner.

Following the luncheon, the group returned to the Wabash College campus where the meeting was resumed in Waugh Hall. The afternoon session was called to order at 2:00 p.m.

"How to Make a Bird Identification Board" was the topic presented by a representative of the Biology Club at Lew Wallace High School, Gary. Bill Zander showed how such a board could be wired for general use in the laboratory.

The second speaker of the afternoon was Kelly Wise, New Castle High School Biology Club. While discussing the destruction of wildlife on our highways, he showed colored slides of the animals often killed. The general trend of his records showed that the English sparrow, rabbit, and the opossum were killed most frequently.

"Somatotyping" was the topic presented by Jim Heuston, Science Club, Howe High School, Indianapolis. He explained how the body build of a human being somewhat determines the characteristics of his personality.

Vivian Schilling, Shortridge Chemistry Club, Indianapolis, described a geology field trip taken by a group of high school students. While showing pictures of the ancient animal fossils, she named the areas where these fossils could be found. Gastropods, crinoids, and brachiopods were several of the more common fossils located by the group.

Charlie Bob Ellis, Junior Academy of Science, University High School, Bloomington, presented the next topic. By using an oscillator, he showed the group how radio waves are transmitted through the air.

The last speech of the afternoon was given by Watson Laetsch, Science Club, Howe High School, Indianapolis. He discussed his experiments in culturing pathogenic molds found on the human body.

Several student representatives from various science clubs gave suggestions to the group for planning money-making projects.

President Richard Elzay then turned the meeting over to Professor Howard Michaud who announced the winners of the best girl and best boy titles. Judith Douthitt, Bloomington High School National Scientific Honor Society, was chosen to be "Outstanding Girl." The title of "Outstanding Boy" went to Tao Yuan Chen, Chemistry Club, Shortridge High School, Indianapolis.

Following these announcements, President Richard Elzay adjourned the meeting at 4:00 p.m.

NECROLOGY

WILL E. EDINGTON, DePauw University

BENJAMIN HARRISON GRAVE

Monrovia, Indiana	Indianapolis, Indiana
December 5, 1878	January 25, 1949

In a memorial service for Benjamin Harrison Grave, held in his home a few days after his death, by friends and associates from DePauw University and Wabash College, the tributes to the man and his work were spoken by both men and women in no prearranged ritual but only as the spirit moved them. This was in keeping with the life that Ben Grave had lived, for as a birthright Friend his whole career was characterized by simplicity, sterling integrity and fearless defense of what he believed to be right and true.

Born in Monrovia but descended from Wayne County pioneers, most of his life was spent in Indiana. Graduating from the Friends Central Academy at Plainfield, he entered Earlham College and received the Bachelor of Science degree in 1903. He immediately went to Carleton College as an instructor in biology where he remained until he received the M.S. degree three years later. Following a year at Earlham College as Assistant Professor of Biology he entered Johns Hopkins University as a Fellow where the Ph.D. was conferred on him in 1910. He spent the next three years as Professor of Zoology at the University of Wyoming, followed by seven years at Knox College as Professor of Biology. In 1920 he became Professor of Zoology at Wabash College, leaving there in 1928 to accept the departmental headship in Zoology at DePauw. Dr. Grave became a Fellow in Embryology in the Marine Biological Laboratories at Woods Hole, Massachusetts, in 1919, and he spent a number of summers there as an instructor. He was also a Fellow at Yale in 1926-1927. He was stricken by a serious illness and was forced to retire in 1942 as Emeritus Professor of Zoology. Following his retirement he remained in Greencastle, except for short periods spent in hospitals and clinics in an attempt to relieve his suffering, until his passing on January 25, 1949.

Dr. Grave as a teacher and lecturer had that intense enthusiasm that was contagious. Students who began their work with indifference were inspired to continue their study on to advanced degrees and the records show that approximately 85 per cent of his major students received advanced degrees either in zoology, medicine or kindred sciences. He possessed an uncanny ability quickly to recognize and appraise the innate abilities of students and many of his former students are now in the leading laboratories of the United States. He insisted on accuracy, rigor and high educational standards and he had little patience with indifference, laziness or superficiality. He was deeply interested in spiritual values and the problems of human welfare and was a bitter foe of intolerance or tyranny in any form either on or off the campus.

Dr. Grave was a member of the American Association for the Advancement of Science for almost forty years and was made a Fellow in 1915. He was also a long time member of the American Society of Zoologists. He joined the Indiana Academy of Science in 1920 and was active in its work, serving as chairman of the Zoology Section several times and also on the Membership Committee. His first paper before the Academy was presented in 1924 and this was followed by others of which a half dozen were published in the *Proceedings.* His research and publications in the *Proceedings* and other scientific journals were in the fields of embryology and physiology.

Dr. Grave derived a deep and intense enjoyment in the study of nature. An athlete in his undergraduate days and holder of several campus records in track and field sports, he was never happier than when he was on a hike in woods or along streams, and it was not unusual for him and Mrs. Grave to take long moonlight walks as long as his health permitted. Dr. Grave recognized no conflict between religion and science and his studies in nature only strengthened his faith in the supreme good. This faith characterized his work and influence on the numerous successful students who constitute a living memorial to his memory.

CARL F. HANSKE

Kiel, Wisconsin	Indianapolis, Indiana
September 13, 1892	November 28, 1948

Less than a century ago, long after a number of Indiana colleges had been founded, the first high school in Indianapolis was established. Known as the common people's colleges these high schools became just that, and it is difficult for one to realize the tremendous influence such great high schools as Shortridge, Arsenal Tech, and Manual Training, with numbers in attendance greater than any but the largest Indiana universities, have wielded and continue to wield on Indiana and American thought and action. Likewise the great science departments of these high schools pour out a never ending stream of more or less scientifically minded and scientifically enthusiastic youngsters from whom come and will continue to come the scientists who make America great. Instructor in such a department for twenty-nine years, twenty-two years of which he served as Head, Carl F. Hanske was widely known and prominent in high school scientific circles and his untimely death on November 28, 1948, at the age of fifty-six years, is much to be regretted.

Carl F. Hanske was born at Kiel, Wisconsin, where he spent his boyhood and received his grade and high school education. He entered Ripon College and following his graduation in 1913, he became a science teacher and later principal in the Menominee, Wisconsin, High School. Early in 1918 he entered the army, serving at Yale University in Gas Defense in the Chemical Warfare Division. Following his discharge from the army he came to Indianapolis in the Fall of 1919 as a teacher in chemistry in the Emmerich Manual Training High School. He was made Head of the Science Department in 1926, which position he held at the time of his death. He also completed work for the M. A. degree in 1929 at the University of Wisconsin. He taught summer school at the Culver Military Academy in 1921 and 1922, and directed the Manual High school night school from 1941 to 1943.

Mr. Hanske was a very stimulating teacher and capable administrator, who had deliberately chosen to enter the field of education rather than that of chemical engineering for which he was also prepared. Of a kindly and friendly disposition he endeared himself to his students and others and he frequently made his scientific discussions more interesting and effective through his humourous approaches and keen wit.

Mr. Hanske was an excellent photographer and he had considerable talent in drawing and painting. His interest in science was general and his teaching was enhanced by several trips to Cuba and a summer spent in Europe.

Professionally Mr. Hanske was prominent in the Federation of Indianapolis Public School Teachers, having served as treasurer and vice-president. He was active in the Central Association of Science and Mathematics Teachers and only his illness prevented his having a very active part in the Association's annual meeting in Indianapolis in 1948. He was also a member of Phi Delta Kappa educational fraternity. Mr. Hanske had been a member of the Indiana Academy of Science since 1945.

THOMAS FREDERICK HARGITT

Waldron, Indiana — Bloomington, Illinois
September 30, 1881 — June 1, 1949

Thomas Frederick Hargitt was born near Waldron, Indiana, and was related to Charles Wesley Hargitt, one of the Founders of the Indiana Academy of Science. Thomas F. Hargitt received his elementary education in the Decatur County public schools. In 1903 he began teaching in Indiana schools and between sessions attending the Indiana State Normal School at Terre Haute, from which he graduated in 1915. During the next four years he taught in Cynthiana in Posey County. He entered Indiana University in 1919, received the A. B. degree in 1920 and the M. A. degree the next year. Following a year as Professor of Physics at Kansas Wesleyan University, he returned to Indiana University and completed his work for the doctorate in 1924, serving as an acting instructor in physics during the last year. He accepted the professorship of Physics at Illinois Wesleyan University in 1924 and remained there until illness forced his retirement some four years before his death on June 1, 1949. During the last World War he was on leave to teach Navy V-12 men for eight months at Wesleyan University, Middletown, Connecticut, and at Illinois State Normal University from August 1943 to June 1944.

Dr. Hargitt was recognized as a scholar. He was intensely interested in the discoveries of modern physics and their influence on philosophic thought and this interest enabled him to convey a certain enthusiasm to his students, particularly those in his advanced courses, for the subject of physics, so that many of them have made exceptional advancement since graduating from Illinois Wesleyan. He was a man of small stature, clear blue understanding eyes, a ready smile and infinite patience, whose ability as a teacher was recognized by both his students and Faculty associates. While primarily a teacher he had done some research work in sound and he was the author of *Physics Experiments Laboratory Manual* published in 1933.

Dr. Hargitt was a Fellow in the American Association for the Advancement of Science and he held memberships in the Optical Society, the Society of American Physics Teachers, the Physics Teachers of Illinois, the Illinois Academy of Science, and Sigma Xi. He joined the Indiana Academy of Science in 1923 and while unable to attend its meetings he had maintained his interest in its work through the years.

GEORGE DONALD KLOPP

Reading, Pennsylvania	Indianapolis, Indiana
July 1, 1908	May 30, 1949

The sudden death of George Donald Klopp on May 30, 1949, at the age of forty, came as a great shock not only to his family but to his students and associates at Shortridge High School and numerous friends at Indiana Central College and in the Junior Academy of Science. And what is more to be deplored is that he was stricken while at the height of his powers and at a time when he had become most effective.

He was born at Reading, Pennsylvania, but was brought to Indianapolis as a boy and completed his public school education at Shortridge High School. He immediately entered Indiana Central College, in 1928, and was graduated in 1932. The following year the Master's degree was conferred upon him at Butler University. He then returned to Indiana Central College as an instructor in botany which position he held for four years. In 1931 he also became an assistant to Dr. William P. Morgan, Professor of Zoology at Indiana Central College, in Indiana University Extension work and he continued in this work for seventeen years. He began teaching at Shortridge High School in January, 1939, and remained there until his death.

Mr. Klopp's Master's thesis was research in plant cytology but he was mainly interested in field work in botany and zoology. He was very skillful in dissection work and through his suggestions new laboratory methods were originated in the Indiana Central College and Shortridge laboratories. He had made a hobby of collecting a great mass of material in the form of posters, scrapbooks, demonstrations, reproductions of colored bird plates and kodachrome slides of flowers in their natural state, to be used in his teaching, and his large collection of plates and slides and his extensive file of scientific articles are now at Shortridge. He spent three summers as a nature guide at McCormick's Creek State Park and three summers as nature instructor at Camp Chank-Tun-Un-Gi, in the Indianapolis Boy Scout Area, and he was active in Boy Scout Merit Badge work on birds and other nature study up to the time of his death. He possessed a pleasing personality and his deep interest in character building coupled with his skill and popularity as a teacher made him a real force in his classes and his other youth work.

Mr. Klopp joined the Indiana Academy of Science in 1930 when he was only twenty-two years of age, and he was active in furthering the Club work of the Junior Academy. He was elected a Council Member of the Junior Academy in 1947 for a term of four years and his passing is great loss to that organization as well as to the Academy itself. Likewise, quoting from a memorial issued by the Superintendent of the Indianapolis Public Schools, "In his sudden death the public schools and the community have lost an outstanding man whose career had demonstrated unusual capacity for public service. His memory will be cherished by all who knew him."

DAVID ANDREW ROTHROCK

Milltown, Indiana	Lafayette, Indiana
January 31, 1864	September 2, 1949

Another tie with the most interesting and probably the most outstanding period in the history of Indiana University was broken with the death of David Andrew Rothrock whose association with Indiana University as a student began over sixty years ago. He was born at Milltown January 31, 1864, and after completing what the public schools of the village offered, as was common in those days, be began teaching at the age of seventeen in a one room country school. Between terms of teaching he attended Indiana University and was graduated in 1892 at the age of twenty-eight. Thus he came under the influence of David Starr Jordan, who left Indiana University in 1891, and John M. Coulter who succeeded Jordan as President.

Following his graduation Mr. Rothrock was immediately employed as an instructor in mathematics and he began his long association with

Robert J. Aley and Schuyler C. Davisson and a little later with Ulysses S. Hanna. These four became known as the "Big Four" in mathematics at Indiana University but this "Big Four", unlike the "Big Four" at the University of Chicago who were primarily research men in mathematics, was composed of outstanding and inspirational teachers of undergraduates whose work resulted in the remarkable fact that in 1930 more members of the American Mathematical Society had received their undergraduate training at Indiana University than at any other University in the country except Harvard.

In 1893 Joseph Swain, a graduate and former Head of the Mathematics Department of Indiana University who had gone with Jordan to Stanford University, succeeded Coulter as President. Robert J. Aley, also a graduate of Indiana University, had succeeded Swain as head of the Mathematics Department in 1891, and Schuyler C. Davisson had been made an instructor in mathematics immediately following his graduation in 1890, as was Rothrock following his graduation in 1892. Mr. Rothrock spent the year 1894-1895 at the University of Chicago and was promoted to an assistant professorship on his return to Indiana University. U. S. Hanna graduated from Indiana University in 1895 and was immediately appointed to an instructorship and thus what were to become the "Big Four" were working together under a President who also was a mathematician. In 1897 Professor Rothrock went to Germany where he received the Ph.D. degree in 1898 from the University of Leipzig. Promotions followed rapidly as he became associate professor in 1900, junior professor in 1905 and professor in 1908. A study of this period from 1888 to 1908 inclusive shows that out of 2084 students who received the A. B. degree at Indiana University one eleventh had majored in mathematics.

Dr. Rothrock was appointed Dean of the College of Arts and Sciences in 1920 from which he retired in 1937 to serve his last active year as Director of Admissions, following which he retired as Professor Emeritus after forty-six years of service to Indiana University. Dean Rothrock was methodical and careful in his records and at the time of his retirement he stated that 8,791 students had been enrolled in his classes. Dr. Aley once said that Dr. Rothrock was the best teacher of mathematics he had ever known, and the history of the period would seem to indicate his excellence within a group of splendid teachers.

However, Dr. Rothrock was more than a university teacher for he was civic minded and a man of action. He served as city engineer for Bloomington for two years and was a member of the Bloomington City Council from 1918 to 1926 and led the movement to construct the waterworks at Griffey Creek to insure an adequate water supply for the city and the University. He was a representative in the Indiana Legislature from 1919 to 1921. He was appointed a member of the State Conservation Commission in 1925 and served eight years with Stanley Coulter and Richard Lieber, all three retiring from the Commission in 1933.

Dr. Rothrock was long a member of the American Mathematical Society and the Mathematical Association of America, and he had been a member and Fellow of the American Association for the Advancement of Science. He was also a member of Phi Beta Kappa and Sigma Xi. He joined the Indiana Academy of Science in 1898, became a fellow in 1906, and was active in its work for forty years, his last service being to help organize the Mathematics Section of the Academy in 1935. In his earlier years before administrative work absorbed most of his time, he did research in invariant theory and differential geometry, and among his publications eight appeared in the *Proceedings* of the Academy. He was also the author of two textbooks, one on algebra in 1904 and the other a trigonometry published in 1910.

Dean Rothrock was prominent in Bloomington Masonic circles and received the Indiana Grand Lodge Award of Gold, given to Masons who have completed fifty years of service. He was active in church work and also in the Bloomington Rotary Club.

Saddened by the death of his wife a few months before and ill himself for eight months, he passed away on September 2, 1949, at the age of eighty-five years, in Lafayette where he had been visiting one of his sons. In David A. Rothrock Indiana had one of its finest citizens and public servants and his work as an educator has brought glory both to the State and to Indiana University.

PRESIDENTIAL ADDRESS

The Responsibilities of a Mycologist

C. L. PORTER, Purdue University

Every science has three objectives; (a) self improvement, which can be accomplished only by investigation and research, (b) a better and more closely integrated relationship with other, and more particularly, closely allied sciences, (c) a recognized responsibility to the public, and to society generally. Mycology must, along with other sciences, recognize these three objectives.

Voltaire once said "If you wish to converse with me, define your terms". When I am asked concerning my profession, I reply that I am a mycologist. The second question follows usually, "What is a mycologist"? I then give the brief dictionary definition—"Mycology is the science of fungi". For some reason the obvious third question does not follow. Either my inquirer is too polite to quiz me further, or he thinks he knows what is meant by the word "fungus". It is fortunate for me that the inquisition stops where it does for a definition of this term is most awkward. The definition for fungus given to my classes is this—"A fungus is a plant without roots, stems, leaves, or chlorophyll, and whose vegetative body is a thallus". Students accept this definition usually without question, as is the nature of students everywhere; but there are many grave doubts in the mind of the professor who gave it. Dr. G. W. Martin, one of our most able mycologists, throws doubt on the initial premise, that a fungus is a plant. Also, the definition as stated does not differentiate between slime molds, bacteria, and the kinds of plants such as molds, mushrooms, etc., that ordinarily come to mind when the word "fungus" is spoken. To overcome this difficulty we must differentiate further between Myxomycetes, Schizomycetes, and Eumycetes. The latter division, Eumycetes, includes the fungi with walled-thalli producing exospores as well as endospores, with some type of mycelial development the most common form of thallus. There is so much diversification and so many exceptions that the Eumycetes can not be too sharply delimited. The mycologist is concerned principally with the Eumycetes. Mycology, in the present discussion includes the Eumycetes only. When fungi are mentioned, reference is made only to Eumycete species.

Fungi were objects of interest to men of the most remote antiquity. There are a number of references in the Bible concerning fungi and their effects. The ancient Greeks and Romans used mushrooms as food. Mushrooms also played an important rôle in ancient and mediaeval toxicology. While ancient records indicate that the knowledge of fungi was concident with the history of man the earlier ideas concerning the nature and origin of fungi were extremely naïve and crude. In the herbal of Hieronymus Bock published in 1560 I find these words, "Mushrooms are neither herbs nor roots, neither flowers nor seeds, but merely superfluous moisture of the earth and trees, of rotten wood and other rotten things." "From such moisture grows all fungi." "This is plain from the fact that all the above mentioned mushrooms, those especially which are used for eating, grow most when it will thunder or rain." "Porphyrius speaks also in this manner and says that fungi are called children of the gods, because they are born without seed and not as other kinds."

The detailed structures of fungi, their life-histories, and their true relationships among themselves and other members of the plant kingdom could not be ascertained until after the development of the compound microscope and the complete overthrow of the doctrine of spontaneous generation.

Modern mycology was brought into being by the advent of a world-shaking catastrophe,—the Irish famine of 1845. The potato disease responsible for the famine was of fungus causation. The control of this disease was a matter of terrible urgency and all of the best botanical brains of the period were concentrated on such a study. It was evident that if the fungus, *Phytophthora infestans* were to be halted in its devastation of the potato crop that more would have to be learned concerning the life history of this causal agent. Anton DeBary made in connection with his study of *Phytophthora infestans* the most notable contribution. He was probably the first investigator to apply the scientific method to the study of a pathogenic fungus. So fundamental was this study of Phytophthora; and others, equally important concerning heterocism of rusts, and the morphology of various other fungi that DeBary is credited with being the father of two lusty offspring—mycology and plant pathology.

Modern mycology had its beginning with the pioneering work of DeBary. American mycology was stimulated by the organization of the Mycological Society of America, in 1931 and the adoption of Mycologia as the official mouthpiece. It was however, the announcement of the discovery of penicillin by Alexander Fleming in 1929 that gave an entirely new direction to mycological endeavor.

Much of the early work relative to fungi in the United States was exploratory and descriptive. New species were being discovered, described, and classified. It was recognized generally during this period that fungi constituted an important part of the flora of any region; that they contributed an important phase of that never ending cycle of nature in which organic life is born, dies, and returns to the elemental forms from which it was derived. If a fungus were found to cause a plant disease it was turned over promptly to the Plant Pathologist. If a fungus were found to contribute to human ailments it was donated to the medical doctor. A fungus that had no apparent economic importance became the property of the mycologist; an object upon which to gaze, to be written about, and then stored away in dusty boxes, perhaps with moth-balls. If you should peruse the pages of Mycologia you will become impressed with the fact that you have become closely akin to the man in Thanatopsis who "in the love of nature holds communion with her visible form" and who has few ambitions beyond communion. You must read through many pages before you will find mention of a fungus that is being discussed because of some economic value which it may possess. The meetings of the Mycological Society has many resemblances to a social meeting of war veterans. The members of the society meet to reminisce concerning collections, and forays, to swap collection experiences and to quibble over moot points of taxonomy and nomenclature.

The discovery that fungi were capable of producing antibiotics and the exploitation of that discovery has altered the mycological outlook very considerably. This new development demonstrated not only that fungi are able to produce products of the greatest economic significance; but it indicated also, that fungus fermentation products of various sorts produced previously only on an experimental scale, could be quantity-produced. Thus, such products could compete effectively with synthetic types of manufacture. As a result of these amazing discoveries an entirely new field of fungus exploration was revealed.

According to Ainsworth and Bisby there are approximately forty thousand valid species of fungi. Most of these species include numerous strains whose physiological potentialities may vary within wide limits. Furthermore, it has been demonstrated in antibiotic production that the substrate may alter markedly the nature of the substances produced by the fungus strain. Thus, if we attempt to make a conservative estimate there are probably four hundred thousand strains or varieties of fungi that must be investigated in order to determine their economic possibilities. These investigations must be made on various types of media, at various pH levels, at different temperatures, under different light conditions, etc. Also, it is not necessarily true that these fungus strains will perform best in cure cultures, but in combination with others.

Perhaps the mathematician can compute for us the possible combinations and permutations that could be made with four hundred thousand fungus strains. There is no field in either physical or biological science that holds so much of promise. It is possible that fungi and their products could revolutionize our present national economy. With the proper sort of cooperative work, results of fungus exploitation will be more spectacular in the future than in the past. The mycologist will be unable to accomplish these things by himself. He must have the assistance of the bacteriologist and the biochemist. I have no quarrel with the contributions that have been made to mycology by these sister sciences, but I do have serious doubts whether the mycologist is aware of his opportunities or his responsibilities.

Mycology, because of the developments of the past decade has ceased to be a hobby-science and is now as utilitarian in its outlook as are the sciences of chemistry, physics, or medicine. The mycologist does have certain responsibilities in connection with the new concepts of his science and some of these responsibilities constitute the material for discussion in this paper.

The chemist in his omnipotence belives that he can solve all mycological problems involving industrial operations. Perhaps the chemist may be efficient with the limited number of fungi with which he works, but in order for any one to learn the limits of the industrial possibilities of any fungus, the origin, natural habitats, morphology, cytology, variability, and relationships must be understood. Such information is available only to persons trained in mycological techniques.

All the fungus species have not been discovered and the geographic distribution of known forms has not been well ascertained. The fungus collectors and explorers laid the foundation of the science of mycology. The services of such men are needed now and in the future. But, the mycology that goes no further than the discovery and naming of species is an impotent science. The enormous number of fungus species that have been described, made classification a necessity and laid the foundation for taxonomy. The perishable nature of the soft-bodied thalli has banned the possibility of an extensive paleontological mycology. Without a comprehensive knowledge of fossil forms a purely natural classification of fungi will never be possible. The present taxonomy is chaotic, and confusing and must in its present condition retard the progress of the science. An example of the sort of condition to which I refer is the confusing state of the taxonomy and nomenclature in medical mycology. The physician and the botanist speak an entirely different language.

In order to revise taxonomy along rational lines it will be necessary to have extensive monographs of the various fungus groups. Monographing is a labor of love. There are no monuments erected to monographers, unless the inconspicuous marker in the pauper's cemetery may be considered a monument. A man who is able to monograph does not have the type of mind, or the time which will permit him to engage in more pecuniary labors. Furthermore, monographs require many pages of printed matter and most botanical journals are not prepared to allot the proper amount of space for comprehensive and exhaustive monographs. Most men engaged in monographic work do not have the means to publish privately. Educational institutions will add new seats to the stadium, or pay for an oil painting of the prize bull, but there is too little advertising value in a fungus monograph to justify an outlay of cash in order to permit its publication. Monographs are essential to the continued development of this science and they must be published before the fullest exploitation of fungus production can be realized. It should be the concern of all botanists as well as those directing the fermentation industries to see to it that monographic publications are made possible.

Monographs may contribute little to our knowledge of fungi if they depend solely on musty herbarium specimens and the inadequate descriptions so often given by the original investigators. There is scarcely a genus of the fungi that would not benefit by a searching, painstaking, and detailed study of all the species that we consider at the present time to be its component parts. Such investigations would reveal that some species have no reason for existence, and that others may belong in entirely different categories. I realize that I am giving aid and comfort to the "lumpers" and "splitters"; but revision of a genus should have a more solid basis in fact than that offered by a cheap publicity. Mycology has suffered enormously from the antics of taxonomic exhibitionists. Thom and Raper in their recent revision of the genera Aspergillus and Penicillium have given to the mycological world examples of the type of studies that need to be made in nearly all genera. At Purdue we are attempting studies of a similar sort with the genera Trichoderma and Verticillium. Too much of the older type of taxonomic research has been based almost solely on comparative morphology studies. New studies in this field must include physiology and cytology, utilizing every technique available to the microbiologist.

The type of research which I am discussing is essential in establishing the industrial potentialities of any fungus species or race. My thesis is that only the mycologist with a background training in chemistry and bacteriology is capable of handling industrial problems involving fungi. The bacteriologist has his hands full if he comprehends the 1500 pages of Bergey's manual. He has neither the time nor the energy remaining to attempt an understanding of the great world of the Eumycetes. The chemist is absolutely incompetent to engage in fungus investigations unless he is willing to devote as much time to the study of mycology as he has to the study of chemistry. There remains then the properly trained mycologist as the only scientist capable of handling in an intelligent manner the multi-faceted problems of industrial mycology.

This then is the responsibility that has been thrust upon the mycologist during the past decade. Living up to this responsibility is not only a matter of adequate preparation but includes also a change in the mental attitude which he has toward his profession. The mycologist may lose his opportunity and evade his responsibilities because of two very unfortunate fixations. First, many mycologists object to the fun being taken out of fungi. They dislike leaving the peaceful contemplation of beautiful and interesting fungi and knuckling down to the difficult task of learning just what a fungus can do; and finding that, to learn how to make it still more productive. We are told that a number of the eminent mycologists refused to attend a recent annual meeting of the American Mycological Society because there were too many papers dealing with purely practical aspects of fungus research.

The other complex which may limit our opportunities has to do with what Dr. Neil Stevens termed "The excessive meekness of American botanists." The chemist, the physicist, and more lately, the bacteriologist have demonstrated the utility of their sciences. Their discoveries have been associated closely with those technological developments that have contributed so much to our modern mechanical civilization. The publicity from these discoveries has made the public believe that their finely equipped laboratories and their high salaried personnel have been worth all the cost. Graduates from these sciences are easily placed as well paid technicians in industry. The botanists know that the animal world is absolutely dependent on the plant world, but they have a way of losing all the publicity advantages of plant improvement which more than any discovery of the chemist or the physicist has kept mankind from sinking into oblivion from famine and disease. Dr. William Trelease has said that "the chief difficulty with botany was that as soon as it became practical it was called something other than botany:—agronomy, horticulture, genetics, forestry, etc. The chemist and the physicist do not seem to have the same trouble; no matter what the practical angle may be, it is still chemistry or physics. Is the botanist meek because he is robbed of the utilitarian phases of his subject; or is he robbed because he is meek? Some one has said that you never have to inquire for the botany building when you go to a strange campus:—just search for the most run down and the poorest equipped building on the campus. Mycology suffers from this same type of robbery. Its practical phases become Plant Pathology or Medical Mycology. Now, there is a movement on foot to take the industrial mycology away from the parent science and place it under a new name,—"microbiology". The inferiority complex so often felt by the botanist and the mycologist in his contacts with other scientists arises from the fact that he can offer only theoretical solutions to the problems of mankind. Today the properly trained mycologist is just as necessary to our society as is the chemist or the physicist. He must not only realize this, but he must be aggressive enough to claim his share of the rewards that are attached to services rendered. The mycologist has every right to feel as Marmion felt when he found himself surrounded by critical and supercilious Noblemen—"And if thou sayest I am not peer to any Lord in Scotland here; lowland or highland; far or near; Lord Angus, thou has lied."

Given the desire to become practical, how do we sell our product to the public? It is my belief that those of us engaged in school work have the immediate task of impressing our students with the opportunities and the far reaching objectives of our science. Taxonomy should be taught as well as the comparative morphology which is so necessary for the proper comprehension of taxonomy. Taxonomy is the essential corner stone of any natural science whether it be zoology, entomology, bacteriology, botany, or mycology. The student should be made to realize that there is no substitute for taxonomy and there is no easy way to learn that subject. A proper understanding of taxonomy requires memory and a proper appreciation of the philosophy with which the subject is permeated. A man who is lacking in orderly mental processes can never become a taxonomist.

Fungus physiology is a science which is able to inform us concerning the possible productiveness of a fungus. Fungus physiology is a study that will be so much extended in the next fifty years that it will make present knowledge seem primitive. Much of what we know concerning the functions of fungi is based on superficial and inadequate data; and these data are based on a few species only. Until we know as much about many of the forty thousand species of fungi as we know about *Aspergillus niger*, the essential science of fungus physiology is going to remain inadequate. No area of research offers so much promise, or so much of challenge as this one.

Following the advent of penicillin there was an urgent demand for the mycologist to improve industrially important strains of fungi. This had a very close similarity to the more conventional demand for the farmer to improve his milk cows. Whether a fungus strain is improved by a breeding program or by the production of induced mutations the ever increasing science of fungus genetics must be comprehended. The fungus genetics that is available today is pretty sketchy and involves relatively few species. Further progress in this direction is dependent on cytological research. An adequate fungus-cytology must await new techniques in staining and microscopic observation. These deficiencies will disappear in time, but they again call attention to research possibilities in mycology.

There is one phase that is too often ignored in the mycology teaching program. There are institutions where a student may get a degree in mycology having learned all of the ancient lore of the subject. He knows all the nomencatorial rules and can argue them pro and con in the same way that a lawyer knows the criminal statutes of his state. He is able to recite the fungus classification from Allomyces to Zythia, and he is thoroughly familiar with all known variations in classification systems. He has a green thumb and is able to make the most difficult cultures to grow and fruit. He knows every fungus enzyme and can name every organic acid produced by fungi. He can write the most complicated chemical formulae that involves fungi. In spite of all this knowledge which is certainly well to know, this student may have trouble in the identification of even the most simple molds, nor will he know the techniques that will enable him to make necessary identifications. The principles and practices of identification are absolutely essential to the training of the modern mycologist; especially if he hopes to go into industrial employment. A department teaching identification must have a large pure-culture collection with the facilities necessary to maintain the cultures in typical form. Laboratory courses should be organized to give intensive and rigorous training in identification. The success of such a program may be judged by the ability of a student to identify a large number of "unknowns".

The productive mycologist will not fail to tell his story wherever and whenever the opportunity presents itself. Much information that would be helpful now lies buried in incompleted and unpublished manuscripts. If students are taught properly they will be informed as to the investigational possibilities of the subject, and guided into research channels resulting eventually in publication. Few major discoveries in any field of science have been made at one time or by one man. Most of our discoveries and inventions have been made possible by the piecing and fitting together of a countless number of data. It is almost criminal to keep any known facts from co-workers in the field of science. The results of research become buried because of the inertia of the worker, a change of the field of interest, or deliberate suppression in order to prevent another investigator from "arriving first". Many times the investigator is too modest to realize that his few data may add up some day with others to something that will be tremendously important. The State Science Academies have been very useful in serving as publication media for young scientists to make public the results of important but preliminary research.

In the beginning of this discourse I state that every science had three objectives; one of these being a recognized responsibility to the public. The discoveries resulting from mycological research have fulfilled a part of this objective, but we have not been doing so well in another public relationship. We have not made our science known to and understood by that hypothetical, but very important man,—"the man on the street." Mycology along with other sciences takes pride in speaking a language that is understood only by its initiates. Technical terms in any field are unavoidable whether it be fungi, baseball, needlepoint, racetrack gambling or canasta. Many times however, descriptive terms in common usage will serve as well and be more easily understood. For instance, in describing the common umbrella-type mushroom we can use cap instead of pileus; gills instead of lamellae; stalk instead of stipe; ring instead of annulus, and cup instead of volva. Writing on technical subjects for the benefit of the public should not only utilize easily understood terms, but attention should be given also to sentence structure and length. In his recent book, "Art of Plain Talk" Rudolf Flesh speaking of the relationship of sentence length to ease of understanding classifies sentences as follows:

Very easy to understand	Eight words or less
Easy to understand	Eleven words
Fairly easy to understand	Fourteen words
Standard	Seventeen words
Fairly difficult	Twenty-one words
Difficult	Twenty-five words
Very difficult	Twenty-nine or more

Flesh states that scientific English averages thirty words a sentence.

It would seem that most scientists pride themselves in making their subject as difficult to understand as possible. Perhaps this is a remnant of the dear, dead days when the robber barons of industry were wont to exclaim "The public be damned." Perhaps it partakes the mental complex that makes a man desire to join a fraternal organization so that he may have a few secrets from his wife and the other underprivileged members of mankind. Perhaps the basic reason is just snobbery—the desire to be exclusive. Whatever it is that makes a scientist write in a language that may be understood only by a few of his fellow scientists, it is a childish weakness and should be outgrown. The science that makes itself understood to the reading public will be the science that will receive public sympathy and support. More important than this; the science that serves most will be the science that is understood and appreciated by the most people. It is a weak argument to claim that a man capable of doing technical writing is incapable of writing for the general public. If this is true it is a fault in our educational training for scientists. Do we mean that we are to insist that the scientific scholar should be able to read and write in two other languages in addition to his native language, but it is not necessary to teach him to write and speak in the vernacular of his own people? It is often claimed that a popular account of a scientific discovery is a distorted account. It is my contention that if you can write in technical language without distortion you should be able to write in common language. If you can relate your research in such a manner that it is interesting to a fellow mycologist you are lacking in ability if you can't write in a manner that will interest the nonprofessional man. In addition to our language requirements in the University, we should add a further requirement; that graduate students be able to describe the most difficult phases of their own research in a manner that would be acceptable to the science sections of a popular magazine such as Time magazine. Most of our scientists would benefit by a thorough course in journalism. However, it is not only an inability to write in simple language that does a disservice to the public, but also, some sort of an idea that prestige will be lost if one should write in interesting and understandable English. So long as this inane conception prevails so long will a scientist be regarded as a longhaired, impractical intellectual who has lost most of the attributes that make him human. As long as he is so regarded, the science which he represents will fail to meet the needs of the people who should be served.

Mycology has lived through the childhood when its devotees were happy and satisfied to pick mushrooms in the cool damp woods of early spring. It is growing toward a healthy maturity. It is our job as mycologists to see it does not loaf, procrastinate, or deviate from a path of service.

ANTHROPOLOGY

Chairman: W. Wallace, Indiana University

H. E. Driver, Indiana University, was elected chairman for 1950.

ABSTRACTS

A note on the physical anthropology of the Dominica Caribs. Elias Adis-Castro, Indiana University.—The Caribs of the island of Dominica are the sole remnant of the once powerful and large Carib tribes of the Antilles. The rest were exterminated or became greatly mixed because of their war-like nature and maritime expansion, on the one hand, and Spanish colonization and the introduction of negro slaves, on the other. Measurements and morphological observations on thirty-six adult males and eighteen adult females were analized to describe what the original inhabitants of the West Indies were like and to determine their relationship to a number of South American Carib and Arawak tribes. Due to the inaccessibility of the interior of the island and the lateness of the migration from the continent, it can be demonstrated that this series of Dominica Caribs show very little evidence of hybridization and are most closely related to the Carib and Arawak tribes of the Guianas.

The spatial and temporal distribution of the notched rasp in the New World. Harold E. Driver, Indiana University.—The notched rasp is a musical instrument found in North America and the Antilles. There are no references to it from South America. Ethnological specimens are most often made of a piece of wood in which from a dozen to perhaps 50 notches have been cut. This is rubbed back and forth with another stick or sometimes a bone. The lower end of the notched stick is often rested on a basket, pot, or gourd which acts as a resonator. Archaeological specimens are mostly of bone, wood being seldom preserved in the ground. They are found in the same area as the ethnological specimens. To delimit this area more specifically, it includes the Antilles, Mexico, and the United States. The most northern tribes using the rasp, the Okanagon and the Plains Cree, straddle the Canadian border. The earliest specimens date from the first half of the first millenium of the Christian era and are located in Mexico, Texas, and Kentucky. While the rasp is also known in the Old World, it is more conservative to consider the New World forms as of independent origin until further research yields more evidence of its diffusion from one hemisphere to the other. The New World forms are thought to have a single origin.

Skeletal material from the Archaic horizon in Posey County, Indiana, George K. Neumann, Indiana University.—The description and analysis of six crania from an Archaic shell mound that was situated on the bluff that overlooks the left bank of the Wabash, south of New Harmony, shows that the most ancient inhabitants of southern Indiana were closely related to the shell mound people of Kentucky and Tennessee, and somewhat more distantly to the Basket-Makers of the Southwest. An antiquity of from five thousand to fifteen hundred years has been variously ascribed to sites of this kind. These early nomadic hunters and collectors were of relatively slight build, small stature, and had medium proportioned heads and faces.

A method for analyzing numerical systems. ZDENEK SALZMANN, Indiana University.—The description of numerical systems in linguistic and ethnographic literature has so far failed to be wholly structural. A method for a structural analysis is proposed in the application of three patterns which are coexistent in almost any given numerical system. The three patterns are the frame pattern, the cyclic pattern, and the operative pattern. They all are definable in terms of morphology. (For paper see WORD 6:1)

Food Animals Used by the Indians at the Angel Site

W. R. ADAMS, Indiana University

This report is based on the laboratory identification of a sample of the bones excavated at the Angel Site (2) in Southwestern Indiana. Although the selection was essentially at random, an attempt was made to obtain material from a wide geographical area and to obtain vertical depth series. Thus, although most of the faunal remains were taken from the main village excavations, part were chosen from the temple mound (Mound F), located one-half mile to the Southwest. Village site data represented excavation levels ranging from 0.0 feet, the modern ground surface, to 2.4 feet, the approximate vertical extent of the midden material.

The sample was first divided according to biological classes, as shown in Table I, and was found to consist of 837 Birds, 222 Fish, 388 Reptiles, 4,640 Mammals, and 2,459 bone fragments which, because of lack of markings, could not be identified. Probably the greatest single factor determining the large size of this latter group is the aboriginal practice of breaking bones to obtain marrow. The inability to identify these fragments is actually of little consequence since they represent in nearly all cases, portions of the diaphysis or shaft of long bones, the joints of which are identified in the remainder of the sample. The true sample then can be said to consist of 6087 identifiable bones and fragments.

The mammal bones were then separated into their respective species as shown in Table I. The "residue" shown in this table includes mammal bones which I have been unable to identify to date for lack of adequate comparative material.

It should be noted here that this sample comprises only a small part of an estimated quarter-million bones recovered from this large village site. In view of this, any suggestions drawn from this study must be considered tentative. For instance, the data indicated that in certain areas of the village large game animals were preferred to small species, while in other areas small animals seem to have been preferred to the larger ones. In one sub-division lying along the river bank, a very high proportion of reptile bones, consisting almost entirely of turtle, was encountered. These differences hint strongly of a possible specialization of hunting, but may be purely an artifact of the sampling method.

An analysis of species occurrence by levels revealed no significant vertical trends, so we can assume *pro tem.* that the food habits remained comparatively stable during the period of habitation.

When comparing the faunal remains from many archaeological sites with checklists of the animals in that area at present, one is impressed by the number of species lacking in the aboriginal refuse. For instance, although some 82 species of mammals were probably indigenous to the vicinity of the Angel Site at the time of habitation, only 21 species were identified in the refuse (1). Table II was made to show the species utilized and their relative importance in this and other midwestern sites.

Bird remains were plentiful in the Angel Site sample, where they constituted more than one-eighth of the total identifiable sample. Fish and reptiles (turtles) were also of some importance as together they form approximately one-tenth of the sample. The remains of bats, moles, shrews, and many of the smaller rodents were lacking in this material. Moles and several species of mice have been reported from other midwestern sites, but I think in every case these represent individuals which died in burrows.

The opossum appears to have been relatively important at this site although shunned by the Illinois Hopewell and Mississippi groups. The present northern range of this animal includes Illinois, but may have been more limited in prehistoric times.

Raccoon formed a substantial article of diet among most midwestern groups, ranking third among mammals at the Angel site.

Marten, fisher, weasel, mink and otter are absent or practically so among the refuse of all groups. Although marten and fisher may have been rare or absent in the hunting area of the Angel Indians, weasel, mink and otter must have been rather plentiful. However, since these were considered as fur animals there is a possibility that they were skinned on the spot rather than carried into the village.

Skunks seem to have played a very minor role among these midwestern groups.

No remains of badger were found at this site, nor would they be expected since their historic range lies north of central Illinois (3, pp. 348-352).

Wolves, coyotes and foxes were of sporadic occurrence among these sites and of little importance in any of them, while domestic dogs were numerous among Illinois Hopewell, but of little consequence among others.

In a tabulation of species from many midwestern sites (1, Tables 5, 6, 7), the cougar is conspicuous by its absence in earlier sites and its almost constant occurrence in Middle and Upper Mississippi sites where it likely supplied both food, hide and ornaments.

Gray and fox squirrels were quite important at the Angel Site, the former being the second most numerous mammal in the sample. While present in the refuse of many other sites, they seldom appear in significant numbers.

Beaver were fairly important to most groups and probably were used for both food and fur.

The rice rat has been reported only from Middle and Upper Mississippi sites in Southern Ohio, Southern Indiana and Central Illinois. The former two locations are just within the known northern range for this species (3, pp. 202-204). However, its presence in Central Illinois represents either a new northern range or transportation, perhaps as pets, into the area from the South.

Muskrat show a fairly widespread aboriginal usage, although they are much less represented in this sample than would be expected.

Porcupine bones have been identified at the Angel Site, but not in this testing of material. They have been reported from several Mississippi sites and must have served as a food source, although their quills may have been utilized in some manner.

Rabbits were used to a considerable extent by Mississippi peoples but seem to have been avoided by Woodland groups. Myer (4, p. 608) points out that the avoidance of rabbit may be due to the belief of southern Indians that rabbit flesh imparts timidity to the consumer. Among certain Eastern Woodlands groups the rabbit represents the Culture Hero and may have been avoided for such reason.

Remains of the swamp rabbit *(Sylvilagus aquaticus)* have not been identified as such from any site in the Ohio Valley to my knowledge. One specimen from the Angel Site may well represent this species by reason of its greater size, but for lack of adequate comparative material, it was listed in this report as the cottontail *(Sylvilagus mearnsii)*.

Wapiti were of widespread use and because of their large size must have been much in demand. Deer, however, seem to have formed the staple animal food for all of these groups, as evidenced by the tremendous numbers of their bones.

The absence of bison remains at the Angel Site has been a particularly disturbing problem. It was thought that perhaps since these inhabitants were a sedentary, agricultural people, they had no need or inclination to hunt this animal. This explanation is considerably weakened by the presence of bison remains in other related sites. In most known bison-hunting tribes the meat is removed from the carcass where it is killed, so one would not necessarily expect to find a large number of bones in the village refuse, even among persons largely dependent on them (5, p. 35). There is an even stronger probability that the variety found in this region during early historic times were representatives of the Eastern Bison, being driven west by European settlement. When it is seen that other Indiana and Ohio sites lack bison remains, this possibility becomes more acceptable. It seems likely then that the Angel Site was deserted for a considerable length of time before bison filtered into this region.

This investigation has raised a number of problems rather than actually solving any. A great deal of work will be involved in answering these questions, and it would be greatly simplified if archaeologists would refrain from listing species in their reports as "Present", "Common", "Abundant", or simply as "25 bushels of deer bones."

Although the fauna from the Angel Site will be rather continuously identified for an indefinite time in the future, the author will be glad to undertake identifications from other Indiana or Midwestern sites at any time.

TABLE I. Fauna from the Angel Site

BIRDS	837
FISHES	222
REPTILES	388
MAMMALS	4640
UNIDENTIFIABLE	2459

Opossum—*Didelphis virginiana*	67
Black Bear—*Euarctos americanus*	9
Raccoon—*Procyon lotor*	182
Eastern Skunk—*Mephitis nigra*	2
Illinois Skunk—*Mephitis mesomelas*	5
Eastern Gray Fox—*Urocyan cinereoargenteus*	2
Gray Wolf—*Canis nubilus*	1
Domestic Dog—*Canis familiaris*	12
Adirondack Cougar—*Felis cougar*	34
Bay Lynx—*Lynx rufus*	10
Southern Woodchuck—*Marmota monax*	3
Franklin Ground Squirrel—*Citellus franklinii*	1
Gray Squirrel—*Sciurus carolinensis*	280
Fox Squirrel—*Sciurus niger*	166
Carolina Beaver—*Castor canadensis*	35
Rice Rat—*Oryzomys palustris*	19
Muskrat—*Ondatra zibethica*	1
Porcupine—*Erethizon dorsatum*	x
Cottontail Rabbit—*Sylvilagus floridanus*	47
American Wapiti—*Cervus canadensis*	20
Virginia Deer—*Odocoileus virginianus*	3609
Residue	133

TABLE II. Species Percentages from Various Reports

	Indian Knoll	Illinois Hopewell	Angel Site	Illinois Middle Miss	Tennessee Middle Miss.
Birds	5.85	4.1	13.7	14.5	9.3
Fish	1.18	17.4	3.6	12.6	3.1
Reptiles	2.02	10.2	6.3	3.8	4.2
Didelphis virginiana	.14	...	1.1	...	1.1
Scalopus aquaticus	...	...	...	...	...
Euarctos americanus	.01	2.8	.1	...	4.6
Procyon lotor	1.47	2.2	2.9	.9	2.7
Martes americana	...	...	...	...	...
Martes pennanti	...	...	...	...	...
Mustela cicognanii	...	...		...	...
Mustela vison	.01	.2	...	...	...
Lutra canadensis	...	...	...	...	...
Mephitis nigra	.01	...	.03	...	...
Mephitis mesomelas	.01	...	.08	...	...
Taxidea taxus	...	.2	...	...	...
Vulpes fulva	.03	.2	...	.07	...
Urocyon cinereoargenteus	.03	...	.03	.07	...
Canis nubilus	...	.2	.01	...	...
Canis familiaris	.36	3.4	.2	...	...
Felis cougar	...	...	.5	1.1	1.1
Lynx rufus	.04	...	.1	...	.2
Marmota monax	.26	.75	.04	...	...
Citellus franklinii	...	...	.01	...	...
Tamias sp.	.01	...	...	...	...
Sciurus hudsonicus	...	...	...	...	...
Sciurus carolinensis	.09	...	4.6	...	.9
Sciurus niger	.09	...	2.8	...	.9
Castor canadensis	.05	1.1	.6	.9	.03
Peromyscus leucopus	...	...	...	...	...
Oryzomys palustris	...	...	.3	...	...
Microtus sp.	...	...	...	...	...
Ondatra zibethica	...	.75	.01	.9	.1
Erethizon dorsatum	...	...	x	...	...
Sylvilagus floridanus	.04	...	.8	...	.5
Cervus canadensis	...	5.3	.3	1.9	.2
Odocoileus virginianus	88.37	50.2	59.3	64.1	74.1
Bison bison	...	.6	...	...	...

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Negative Painting of Angel Site and Southeastern United States

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Negative painting is a technique in which a portion of the designing appears on the vessel in the original color of the pottery. The actual process by which this designing was executed is still a problem, however, several techniques have been suggested.

In one process, the portion of the vessel which is not to be colored is covered with wax; the vessel is then dyed and left to dry. After drying, the wax and the dye covering it, is removed thus leaving a portion of the vessel in its original color.

In a variation of this process; after the wax and dye have been applied the vessel is fired, setting the dye and burning off the wax. The final result is about the same as in the first process.

A third method has been suggested in that after a substance has been applied to the area not to be colored the vessel is fired without any dye being used. The process of firing, if controlled properly can change the color of the vessel which is exposed to the air and fire. Properties in the clay itself will help to determine the color change. That part covered would remain in the natural color.

One of the above processes was probably used at the Angel Site in decorating the negative painted pottery there.

With but few exceptions the decoration is confined to the rim of the vessel. On one large fragment the design goes over the entire inside of the vessel, both rim and base. In another instance where several sherds are probably from the same vessel the design is found on both the inside and the outside of the pieces. These examples, however, are rare.

In some instances a coating of red ocher has been placed over the negative design. This film often covers the entire inside of the vessel, even if the negative design doesn't. It is thin enough for the negative design to show through. In four or five cases the application of this direct paint has been controlled to the extent that a design of red ocher has been painted over the top of the negative pattern.

The shape of the negative painted vessels at Angel Site consist mostly of bowls and wide-rimmed plates. Three water bottles, one being an effigy of a woman, were found and enough sherds to represent perhaps a half dozen more bottles. The plates are often rather large; one reconstructed vessel measuring 12½" in diameter with a 3½" wide rim. This rim section is the portion which contains the designing.

The designs of the ware are quite diverse. In approximately 85 percent of the sherds they can be placed in three or four categories with but slight variations. In the other 15 percent, however, the motifs are varied and often occur on just one or two vessels or on only a few sherds.

A large portion of the sherds have geometric designs. The most common of these is the diagonal lines which cover the entire rim of the vessel. There are three types of this pattern: a) diagonals forming chevrons in pyramid fashion going from the inner edge of the rim to the outer edge, b) the same pattern as above only the motif starts on the outer rim edge and builds up toward the inner edge, c) diagonal lines going clear across the rim forming alternately a V-chevron type motif around the vessel rim. In combination with these diagonal lines the so-called "sun-symbol" is sometimes found. This motif is an equal-arm-cross enclosed in a circle. There are about a dozen variations of this pattern; changes being found in the type of equal-arm-cross made and also in the circle which is sometimes double, sometimes radiating. The "sun-symbol" is also frequently found as the only design on a vessel, being placed more or less regularly around the rim.

Another large category of sherds carries a scallop design around the outer edge of the rim. This motif is generally independent of any other design that might be on the rest of the rim. Even when the sherds are covered with a film of red ocher, this outer scallop motif is not always covered.

Of the 15 percent of the sherds with such diversity in their designs some are so stylistic that the pattern cannot be determined. Also, some of the sherds are too small to get the complete design. There are a few, however, that deserve mention.

The owl face is a design which appears on a large plate in combination with a motif looking like the letter N. The plate was broken when found but has since been reconstructed, and it shows that the double motif appears four times on the rim. This is the only example of the owl face found so far at the Site.

The bi-lobed arrow appears on four different sherds. Three of the sherds are covered with a film of red ocher, while the fourth is not covered and the design is so faint that the exact outline is hard to follow.

The stylized bird is a motif which is found in several variations but in most cases there are not enough sherds of the same vessel to allow determination of the complete design. Those few that are fairly complete, however, depict only the head and neck of the bird.

Although this type of pottery decoration is an important item at the Angel Site the number of sherds compared to the total number of all pottery sherds taken from the site appears small. The total number of sherds excavated up to the end of 1948 was 1,719,164 pieces. This figure includes all plain ware, painted ware, rims, vessel lugs and handles. Of this figure 14,559 are painted—both direct and negative. 4054 of these sherds contain negative painted designs.

Negative painted ware is found over a large part of southeastern United States. A few vessels were found at two different sites in northwestern Florida. There are a number of sites scattered over southern Georgia, Alabama and Mississippi which have produced examples of the ware. It appears as far north as Winnebago County, Wisconsin and as far west as a single site in eastern Texas. As far as I know, the greatest number of negative painted sherds has been taken from the Angel Site. This may be due, however, to the method of excavation. At many sites the main point of excavation was in the mounds while at the Angel Site only one mound has been dug, and the rest of the digging has been in the village area. If other sites were dug in the same manner, more negative painted material might be found.

The main area producing this type of pottery appears to be located along the Ohio River, on the Mississippi River below the mouth of the Ohio, and along the Tennessee and Cumberland Rivers. Outside of this area the sites have produced only one or two vessels and in a few cases merely a few sherds.

It is the general opinion of the authors who have reported on these outlying sites that the appearance of negative painted ware was due to trade. In at least one case (Crystal River, Florida) the ware seems to have been made differently from the rest of the pottery at the site.

Negative painting also occurs in parts of Mexico, Central and South America. Most archaeologists believe that the technique of negative painting was developed in either Central or South America and that it was carried in some manner to the southeastern part of the United States. How, when and by what route it reached the Southeast are questions which are still being studied.

Two routes were available, one via the Antilles and the other up through Mexico and across the southwestern part of the United States. Both routes produce gaps where negative painted ware is not found, or at least it has not been found yet.

There is a possibility that negative painting may have appeared in the Southeast as a part of a trait complex. During the Middle Mississippi period a strange cult, which seems to have had no relationship with anything already established in the area, appeared and spread rapidly over the whole Mississippi Valley. Many of the traits of this cult showed Mexican influence. Among these traits are designs such as have been described from the Angel Site—the bi-lobed arrow, owl face and the stylized bird motif, and the technique of negative painting itself.

If this Southern Cult, as it is called, first appeared in the Southeast during the Middle Mississippi period, and if negative painting is definitely a part of this cult then its appearance could be dated between 1300 and 1700 A.D. As yet no one feels free to say that these assumptions can be considered facts. Excavations in both the Southeast and Southwest United States as well as Mexico are still being carried on and another few years may give us more definite information.

Bone Flutes and Whistles Found in Ohio Valley Sites

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About fifty specimens of bone flutes and whistles occur in Ohio Valley archaeological sites. They are perforated, open tubes made from bird bones. Table I shows measurements and information which were obtained from archaeological reports. Where precise measurements were not given by the author, they were taken from photographs and have been marked as approximations in the table.

In 1916 Moore (5) included in his report on the Indian Knoll Site in Ohio County, Kentucky, a photograph of a short bone tube with one perforation. Over twenty years later, Webb and Haag (8) suggested that the object might be a whistle. A much more extensive excavation of the site by Webb (7), reported in 1946, revealed a perforated bone tube whose use was very problematical. It was perforated in a peculiar manner; next to the large rectangular opening was a small, transverse hole. A similar specimen, which was, however, engraved geometrically, was found in a shell mound of nearby Butler County. Concerning the perforations, Webb wrote: "This suggests that some shaft with perforated end might have been thrust into the notch, and if a bone pin could have been thrust through the side holes, the shaft might have been held in position. . . . The bones are hollow from end to end, which had led to the suggestion that this tube may be a musical instrument, the side hole being used to attach a mouthpiece." Webb did not seem at all willing to guess the use of these perforated tubes, and perhaps their inclusion in this paper is not justifiable.

The investigation of thirteen Adena and eight Hopewell reports brought no evidence of the use of bone for flutes or whistles to light. Bone tubes were used in Hopewell pan-pipes. If bone flutes or whistles were present in these cultures, they should have been found. While no Adena or Hopewell village sites have been systematically excavated, nevertheless the material taken to build Adena and Hopewell mounds was from their village sites, and this fill should contain a representative amount of artifacts.

It is significant that ninety-four percent of the reported flutes come from sites of the Middle and Upper Mississippi phases which are fairly late. The three previous occurences of the flute or whistle in the Ohio Valley were very questionable. If the flute first appeared in the Middle Mississippi phase in this area, it would be valuable as a diagnostic trait.

From the Middle Mississippi phase, represented by the Angel Mounds Site, Vanderburgh County, Indiana, come two apparently complete,

TABLE I. Summary of Material from the Literature

	Name and location of site	Source	Length in inches	Number of perforations	Shape of perforations	Identification of bone	Remarks
Archaic Pattern	Indian Knoll Site, Ohio County, Ky.	Moore, 1916	2.75*	1	Oval		"Perforated bone tube (whistle) ?"
	Same as above	Webb, 1946	9.9	2	One rectangular, one round	"Ulnae of the Whooping Crane"	Use is dubious
	Shell mound of Butler County, Ky.	Webb, 1946	8.35	2	Same as above	Same as above	Differs from above only in engraving and length.
Middle Miss. Phase	Angel Mounds Site, Vanderburgh County, Ind.		4.125	7	Round	Radius of large *wading bird*	Produces musical notes
	Same as above		4.063	8	Same as above	Same as above	Same as above
Upper Mississippi Phase		Smith, 1910	4.44*	4		"Bird bones"	*One perforation on reverse side from other three*
	Same as above	Smith, 1910	5.0*	8		Same as above	One vent is only partly drilled

* The asterisk is used to indicate that the measurement is only approximate.

	Name and location of site	Source	Length in inches	Number of perforations	Shape of perforations	Identification of bone	Remarks
Upper Mississippi Phase	Madisonville Site Hamilton County, O.	Hooton and Willoughby	4.12*	7		"Made from the long bones of birds"	"Flute-like"
	Same as above	Hooton and Willoughby	3.19*	6		Same as above	Same as above
	Feurt Mounds and Village Site, Scioto County, Ohio	Mills, 1917	4.0*	3	Usually round, some are oblong	"Made of the radius of various large birds"	"Whistle-like"
	Same as above	Mills, 1917	4.31*	4	Same as above	Same as above	Same as above
	Same as above	Mills, 1917	3.56*	3	Same as above	Same as above	Same as above
	Same as above	Mills, 1917	3.5*	3	Same as above	Same as above	Same as above
	Same as above	Mills, 1917	2.63*	2	Same as above	Same as above	Same as above

Upper Mississippi Phase	Same as above	Mills, 1917	2.78*	4	Same as above	Same as above	Same as above
	Same as above	Mills, 1917	2.5*	2	Same as above	Same as above	Same as above
	Same as above	Mills, 1917	3.0*	3	Same as above	Same as above	Same as above
	Same as above	Mills, 1917	3.19*	2	Same as above	Same as above	Same as above
	Same as above	Mills, 1917	3.19*	3	Same as above	Same as above	Same as above
	Same as above	Mills, 1917	3.56*	3	Same as above	Same as above	Same as above
	Reeve Village Site, Lake County, Ohio	Greenman, 1935	5.5	3	Round	"Bird bone"	Three musical notes; long axis is curved
	Same as above	Greenman, 1935	3.4	4	Round	Same as above	No musical note; long axis is straight
	Tuttle Hill Site, Cuyahoga County, O.	Greenman, 1937	4.5*	5			Three holes on one side, two on the other
	South Park Site, Cuyahoga County, O.	Greenman 1937	2.0*	4			Three holes on one side, one on the other

perforated tubes. Mr. Black, who is in charge of the excavation of the site, kindly lent me the specimens for study. They are almost exactly the same length, and their curvatures are almost identical. Both produced the same note when blown hard with all the holes open, a C four octaves above middle C.

The study of these two objects has convinced me that certain measurements, observations, and photographs or drawings are necessary or desirable, at least, for inclusion in reports on such material. The measurements are best shown on the photographs or drawings. Length, distances from the centers of the holes, and the range of the size of the holes are all important because they were determined by the manufacturer. A tentative identification of the kind of bones which was used should be carefully made in order to aid any classification that might be attempted in the future.

The photographs or drawings would be most useful if they are full-size; but whatever the scale that is used, it should be used consistently. It has been customary to show the side on which the holes are drilled. The distance between the holes and their comparative size are readily apparent in this view, but these measurements can also be shown on a side view, in which the curvature of the bone over the holes is best seen. The curvature is important because no musical note can be attained from a perforated tube which is straight. Greenman (1) reports finding two bone flutes. "(One) specimen gives no musical note. It is possible that the musical note of the other is due to the fact that its long axis is curved, while that of the smaller one is nearly straight." Mr. Black told me that he considered the possibility of musical notes depended on the curvature of the open tube. Therefore, the side view is more indicative of the present musical possibilities of the object than the top view showing the holes. Of course, the ideal portrayal shows the top and side views, as well as a photograph or drawing looking into the large end. The large end of the bone would indicate whether the holes were made on the flattened side of the bone or elsewhere.

Many sites of the Upper Mississippi Phase contain perforated bone tubes. Smith (6) reported finding about four specimens in a Kentucky site. All stages of the manufacture of whistles were found at this site: natural bird bones, bones with the ends broken off, one bone with seven perforations and another perforation partly drilled, and the finished whistle.

The Madisonville site in Hamilton County, Ohio, which was excavated by the Peabody Museum, contained about twenty "flute-like objects." Willoughby (3) describes them as small. The author states that, "judging from the unbroken specimens recovered, the number of holes range from five to nine, the usual number being five or six. The holes were commonly about one half inch apart, but in one specimen the centers of the perforations are placed about one fourth inch from each other, too near, it would seem, for its successful manipulation by the fingers of an adult."

Another large collection of perforated tubes, this time described as "whistle-like," was found by Mills (4) in the Feurt Village Site in

Scioto County, Ohio. He reported, "The specimens . . . were made of the radius of various large birds such as the eagle, hawk, wild turkey and others; by cutting off the ends, thus leaving a hollow straight cylinder . . . Many specimens . . . were found and several show where they had been marked for drilling. The holes were drilled with a flint drill, and were usually three in number. Now and then one would be found with two holes, and occasionally one with four holes. The holes were usually round, but a number show an oblong hole. Frequently the oblong hole would show that it was enlarged from the round hole by burning. The holes for the most part were bored in a straight line, usually equidistant apart; however one specimen was found where two holes were in line but the center hole was to one side."

Greenman (1) found two tubes made of hollow bird bones, with flute-like stops, in the Reeve Village Site, Lake County, Ohio. The larger specimen has three stops and three tones, "but the number of tones does not correspond to the number of stops. The central stop does not alter the tone, and when it is closed, alone or with either or both of the others, there is no musical note. The notes A, B, and C may be produced respectively by closing the two end stops, then releasing one or the other, then releasing both."

The final site belonging to the Upper Mississippi Phase was also excavated by Greenman (2). He found one perforated bone tube at the Tuttle hill Site and another at the South Park Site. Both sites are in Cuyahoga County, Ohio.

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The Relationship between the Folk-tale and Culture Area in Central Africa

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The Congo culture area, an arbitrary geographical division in which similar cultures are found, covers an area which extends roughly from 8° N. to 15° S. Latitude and from 9° E. to 31° E. Longitude. It includes the political subdivisions of a portion of Nigeria, the Cameroons, Spanish Guinea, half of French Equatorial Africa, the Belgian Congo, Angola, and two segments of Northern Rhodesia.

The general cultural characteristics which differentiate the Congo culture area from the other cultural divisions of Africa have been outlined by Herskovits and others in several sources (2, 3). Briefly, the distinguishing trait-complex which differentiates the Congo culture area as a distinct geographic-cultural entity is as follows: (1) the absence of cattle; (2) the dependence upon an agricultural economy; (3) the use of rectangular houses, bark cloth, and raffia weaving; (4) the utilization of ceremonial masks; (5) the practice of body scarification; (6) the development of an art form exemplified by carved human representations; (7) the use of wooden drums; (8) the employment of the throwing knife as currency; (9) the importance of the secret society; (10) the flowering of political organization; (11) the presence of periodically held markets; (12) the importance of the craft guilds; and (13) the significance of the fetish in the religions.

The above list can be reduced by grouping the various elements into a more general scheme which points out that, by and large, the Congo culture area is distinguished mainly by its agricultural, political, and artistic characteristics. Since the folk-tale is considered to be an art form by some students, the obvious development of other art forms would lead the student of the folktale to suspect that a definite pattern of the folk-tales which occur in these similar cultures might be present to some degree. The above cultural characterization does not suggest or imply that there in any uniformity of style, type, motifs, function, or role of the folk-tale within the culture area. The generalizations which have been made have either included all of Negro Africa or that portion of Africa which has been long under European influences (5).

An examination of the literature reveals that this area, and the other areas which surround it, has been subjected to the spasmodic collection of the folk-tales of the indigenous groups which inhabited the area from a time coeval with the widespread interest aroused in Europe following the work of the early comparative folklorists. Concentrated efforts to collect tales, that is, efforts which have resulted in books devoted exclusively to tales alone, have been limited, and the majority of the tales which have been recorded and put into print are to be found in the books, journals, and periodicals which are concerned with the numerous other aspects of African culture, or with folk-tales, proverbs, and lore from other portions of the world. The above mentioned fact emphasizes to the researcher that the bibliography of the material, of necessity, will be very extensive, and that the availability of the versions of the tales will be limited considerably by the relatively few tales which have been spread so thinly throughout a vast number of volumes. In a tentative bibliography of eighty four volumes, a total of 1,573 tales was counted. The largest collection in one volume equaled 170 tales, and nineteen volumes contained less than five tales each.

The bibliography also indicates that tales have been collected from approximately thirty-four tribes in the area, whereas Leyburn (4) lists 332 tribes for Angola, Belgian Congo, and Cameroons alone, while more recent publications give lists which are considerably longer (6). The above statistics merely point out that a vast source of material has been left untouched. Possibly the generalizations which were formulated were influenced by the seemingly simple pattern which other aspects of the cultures presented to the ethnologist, but in light of what has not been done, it is unlikely that the generalizations will maintain their validity.

A linguistic problem also presents itself. The tales have been recorded in German, French, English, and Portuguese, while a few have been transcribed phonemically in the native language of the tribe from which the tale was collected. Concerning this problem, Doke (1, p. 352) writes,

> "In this part of Africa the choice of media and the development of literary work have suffered, as they have almost everywhere in Africa, through lack of cooperation by the pioneer missionaries with workers, in adjoining territories. Each mission worked independently and knew practically nothing of the language or language work of the neighboring mission. Additional artificial barriers of orthography, grammatical treatment, and vocabulary choice in translation were unknowingly raised, which today it is our effort to break down or lessen, so that more concerted effort in literature production may be possible in African vernaculars."

These are common problems to all researchers in folk-tale studies, but the difficulty is enhanced by a seeming disinterest in the folk-tale as an entity by numerous travelers, explorers, and traders who came into contact with the native populations. Those few who were interested and did collect tales were obviously biased by personal beliefs and desires to record stories of a particular type. Consequently, the tales which are in print do not give a complete survey of all forms of oral literature developed in the area.

Since the student of African folk-tales is confronted with the problem of establishing a systematic means of approaching an areal study of the various types of folk-tales which have been recorded, a plan is here offered to aid in the development of such a project. Arbitrarily, the geographical boundaries of the culture area which has already been delineated for other aspects of the cultural picture of the region might serve as the limits of the initial effort of study. To insure a careful examination of the literature, all of the tales which have been recorded in this area must be brought together. Summaries of tales can be utilized in motif and type analyses, but little can be done with style from the summary alone.

To prevent overlapping, the distribution of the tribes from which the tales have been collected should be mapped, and the synonymy of tribal names should be reduced to a minimum. This problem is important, as the following synonymies indicate: Balouba, Baluva, Baqua, Kalosh, Baluba, Louba, Luba, Turruba, Waluba, (6) are all names given to one distinct ethnic group by the several authors who have reported and described them.

A single tale, or a group of tales, out of the context of the culture of which it forms a part, is of no more use as an aid in analysing the culture than is a cultural artifact which is found out of context. Thus an effort must be made to determine the function or role of the tale in the particular culture. This would influence, and be influenced by, the conditions under which various tales are told. Such information must be sought in supplementary material which might possibly contain data and descriptions of the information sought. This ethnographical material might also throw considerable light upon group and individual attitudes toward particular tales and specific raconteurs.

By utilizing the refined techniques which have resulted from the use of type-indexes, motif-indexes, and comparisons between trait-lists and tale-content lists, a more extensive approach can be made to this vast problem of unraveling the puzzle of the tale pattern of central Africa. In this way, the present generalizations will either be substantiated or discarded, and the description of the culture area may be complemented by the addition of a description of a folk-tale area based upon criteria other than generalized tale types.

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BACTERIOLOGY

Chairman: I. C. GUNSALUS, Indiana University

H. Koffler, Purdue University, was elected chairman for 1950.

ABSTRACTS

A tentative plate assay method of vitamin B_{12}. R. E. BENNETT and I. ROY COHEN. Research Department, Commercial Solvents Corporation.—A cup plate assay for vitamin B_{12} has been designed using *Lactobacillus leichmanii* ATCC 4797 and a medium modified from that suggested by Skeggs et al. The assay range is from 0.05 to 2 micrograms per ml, based on growth zones from 12 to 22 mm diameter.

The acetate-acetyl phosphate system of *Leuconostoc*. R. D. DEMOSS and I. C. GUNSALUS, Indiana University.—In a study of the intermediary metabolism of *Leuconostoc mesenteroides*, it became pertinent to determine if an acetyl phosphate forming system existed in this organism, and if so to determine its properties as a possible intermediate step in the formation of ethyl alcohol.

Vacuum dried cells, and a cell-free enzyme obtained from them by sonic oscillation, have been shown to contain an active acetyl phosphate forming enzyme with adenosine-triphosphate (ATP) and acetate as substrates. This enzyme has been shown to possess a metal activator.

The reaction has been followed by measuring both the formation of an anhydride by the hydroxamic acid reaction of Lipmann and by the accumulation of a labile phosphate compound of the acyl type.

The cell-free enzyme preparations when dialyzed lost most of their activity and could be reactivated by divalent ions, of which manganese was the most effective. Magnesium and cobalt were also active. The enzyme from *Leuconostoc mesenteroides* is specific for acetate, that is, does not catalyze acyl phosphate formation with propionate or butyrate.

Multiplication of *Brucella* in the yolk sac of embryonated chicken eggs. KATHLEEN GAY and S. R. DAMON, Indiana State Board of Health.—As one phase of the Indiana Brucellosis Study Project, the embryonating egg was tested as an enrichment medium for the isolation of *Brucella* from blood specimens. The rate of multiplication of *Brucella melitensis*, when injected in small numbers into the yolk sacs of white leghorn eggs of varying ages of embryonic development, was first determined. The growth curves indicated a definite bacterial inhibition by 1- to 2-day old embryos and optimum growth in 5-day old embryos.

As few as 1 to 10 organisms multiplied rapidly when introduced into the yolk sacs of 5-day old embryos. Comparable growth curves were obtained for *B. suis* and *B. abortus*.

A new crystalline antibiotic from an unidentified streptomycete. R. L. HARNED, P. H. HIDY, C. J. CORUM, and K. L. JONES. Commercial Solvents Corporation, Terre Haute.—A new crystalline antibiotic has been isolated from a streptomycete obtained from Nigerian soil. Data on the biological synthesis, isolation, *in vitro* activity, chemical properties, and toxicity in mice are presented.

An in vitro study of the combined effect of drugs and antibiotics on bacteria responsible for urinary infections in man. MARION J. MCBURNEY, DePauw University.—This study has shown that combinations of various drugs are more effective on some organisms than either agent alone. The combined effect was greater when a sulfa drug and an antibiotic were used than when two sulfa drugs or two antibiotics were used.

Combinations of streptomycin and sulfathiazole and of streptomycin and sulfadiazine were bactericidally effective against *Micrococcus pyogenes* var. *aureus, Escherichia coli,* and *Proteus mirabilis.* Complete inhibition of *Micrococcus pyogenes* var. *aureus* was also obtained with penicillin and streptomycin, penicillin and sulfathiazole, and penicillin and sulfadiazine.

Streptococcus sp. was susceptible to the combined action of sulfathiazole, or sulfadiazine, and mandelic acid.

Aerobacter aerogenes and *Pseudomonas aeruginosa* were not affected by the drugs employed either singly or in combination.

The microbiological determination of lysozyme. A. N. SMOLELIS and S. E. HARTSELL. Purdue University.—A rapid, accurate method is described for the assay of lysozyme, based on the increase in light transmission of a suspension of *Micrococcus lysodeikticus.*

The turbidimetric assay, after standardization with a crystalline lysozyme preparation, can be applied to lysozyme in natural material.

The *Micrococcus lysodeikticus* cells used for assay were grown in large quantities, treated with ultraviolet light, lyophilized, and stored in the ice box. These cell preparations were stable and of constant sensitivity.

The assay method was applied successfully to a bentonite-pyridine extract of natural materials. Hens' egg albumin extract contained 0.86 mg lysozyme per ml, dried albumin 19.7 mg per gm, and rat kidney extract 0.024 mg per ml. The lysozyme content of kidney extract could be determined with an error of less than 7%. The assay procedure is adaptable to small or large quantities of lysozyme, is reproducible, and accurate.

Effect of some haloacylamides on multiplication of the vaccinia virus. R. L. THOMPSON and MARIAN L. WILKIN, Indiana University, Indianapolis.—During the course of an investigation to determine the effect of analogs of pyrimidines and purines on the growth of the vaccinia virus in chick embryonic tissues, it was observed that several pyrimidine derivatives containing halogenated acylamide groups in the 5-position prevented viral multiplication. The presence of the pyrimidine ring is not essential for virostatic activity, since the chloracetamido group can be coupled to the benzene ring with the formation of an active substance. Compounds of the latter class structurally resemble chloromycetin. The mode of action of the halogenated acylamide grouping has not been determined.

BOTANY

Chairman: A. R. BECHTEL, Wabash College

M. S. Markle, Earlham College, was elected chairman for 1950.

ABSTRACTS

Some observations on the taxonomy of *Oenothera*, subgenus *Euoenothera* in North America. RALPH E. CLELAND.—The North American Euoenotheras show much variability but few clear-cut boundary lines, and their taxonomy is in a very unsatisfactory state. A study of the cytogenetics of the group is uncovering facts which should make it possible to arrive at a system of classification which will express rather accurately actual phylogenetic relationships. The cytogenetic methods used in this study are briefly described, and the major groupings of phylogenetic significance are described. The possibility of elevating these groupings to the rank of species in any future taxonomic revision should be seriously considered.

An evaluation of fireblight resistance in pear seedlings. T. R. CARPENTER. Purdue University.—Seedlings of *Pyrus ussuriensis* Maxim were inoculated with *Erwinia amylovora* (Burrill) Winslow et al. in, 1) early growth stages in the greenhouse, and 2) later growth stages in the nursery row to ascertain the relative merits of inoculations at the two periods of growth. Seedlings inoculated at the sixteen to twenty-four leaf stage could be divided into three general infection classes; namely, immune, resistant and susceptible. No appreciable resistance was expressed prior to the eight leaf stage. Immune individuals could be detected between the eight and twelve leaf stage. Resistant individuals could be consistently detected between the sixteen to twenty leaf stage. A higher percentage of susceptible individuals were eliminated in the early growth stages in the greenhouse than were eliminated from similar progenies initially inoculated in the nursery row. There was less shifting to lower infection classes during the second year inoculations on the part of the greenhouse inoculated plants than among the seedlings initially inoculated in the first year nursery row. There was a tendency for plants to gain in resistance with age, especially among those plants inoculated in early greenhouse growth stages. A higher percentage of infection was obtained at a minimum greenhouse temperature of 80° F. than at 60° F.

A new life cycle variant of the *Stipa*-mallow rusts. GEORGE B. CUMMINS, Purdue University.— Recently Gäumann (Ber. Schw. Bot. Ges.

57:248-249. 1947) has described *Puccinia sphaeralceae* as a new species, under a preempted epithet, producing aecia and telia on *Sphaeralcea ambigua* Gray in California. The species also is known to parasitize *S. orcuttii* Rose in California and *S. rivularis* (Dougl.) Torr. in Idaho. It represents a new life cycle species in the complex including the macrocyclic autoecious South American *P. digna* Arth. & Holw. on *Stipa*, the demicyclic heteroecious *P. interveniens* Bethel on Mallows and *Stipa*, the demicyclic autoecious *P. graminella* Diet. & Holw. on *Stipa*, the microcyclic *P. sherardiana* Körn. on mallows and the endo-form *Endophyllum tubercutatum* (Ellis & Kellerm.) Arth. & Fromme on mallows.

Possibilities of hybrid vigor in *Liriodendron tulipifera*. I. W. CARPENTER, Purdue University.—Maintenance of *Liriodendron tulipifera* in forest stands in Indiana is desirable since it is a principal source of hardwood veneer stock and is also the state tree. Preliminary investigations into the requirements of this tree led to a study of its reproduction. High seedling mortality was observed in quadrat studies of several different sites. The low germinative capacity of tulip tree has long been known, and an attempt was made to discover if this was due to continual selfing of the flowers.

Trees were cross pollinated with pollen from widely separated geographic localities. The seed thus obtained was compared with open pollinated seed from the same parents as to germinative capacity. Six lots of the hybrid seed and open pollinated seed were grown in the greenhouse and records kept to determine if there was any induced viger. Results indicate marked increase in germinative capacity and possible hybrid vigor.

***Tolypella prolifera* Leonh. found in Indiana.** FAY KENOYER DAILY, Butler University.—A brief description is given of *Tolypella prolifera* Leonh. representing a genus of the algae evidently not found previously in Indiana.

Chlorophyll therapy and its relation to pathogenic bacteria. MABEL M. ESTEN[1], and ALBERT G. DANNIN[2].—The achievements to date in the field of chlorophyll therapy are briefly summarized, with particular reference to the relation of such therapy to the pathogenic bacteria. The derivatives of chlorophyll used in the treatment of diseases, methods of treatment, chief diseases for which chlorophyll preparations have been used, toxicity of these preparations, and the chief results of chlorophyll therapy are reviewed. The efficacy of chlorophyll preparations in deodorizing and healing suppurative and other types of diseases has stimulated research to determine the effect of such preparations on the pathogenic bacteria. Results of research to date indicate that chlorophyll preparations have a bacteriostatic, rather than bactericidal, effect upon pathogenic bacteria in living tissues. (To be published in the Butler University Botanical Studies.)

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[1] Mabel M. Esten, Instructor, Botany Dept., Butler Univ.

[2] Albert G. Dannin, Osteopathic Physician (Retired)

Preliminary report on the phytopathology of *Physoderma graminis* (Busgen) Minden, 1911. K. S. GOPALKRISHNAN, Notre Dame University.—*Physoderma graminis* (Busgen) Minden, first reported for this country from Madison, Wisconsin, was later collected at Ottawa, Canada, northern and southern Indiana, Illinois, and southern Michigan. This chytrid parasitises *Agropyron repens* Chev.; parasitism is systemic in which respect it differs from *Ph. zeamaydis* Shaw. There is a complete inhibition of the inflorescence, and the affected plants are readily recognizable in the field by their erect habit and yellowish color. Infection occurs through the overwintering sporangia in dead disintegrating leaves of the previous season. Artificial infection by inoculating the soil with sporangia was successful. Infection through leaves occurs only in very early stages. The incubation period is from eight to twelve days. The symptoms consist of yellow streaks which gradually coalesce and turn brown until the leaf dies. The peak period of infection in the field is June and there appears to be a second period of infection some time in the fall depending upon the warmth of the weather. In the laboratory the optimum temperature for the germination of the resting sporangia is 29° C. The resting sporangia require a dormancy period of three to four months but the dormancy can be broken by low temperatures (—10° C.), burial in the soil, or alternate heat and cold treatments. Drugs tried so far have not produced any break in the dormancy of the sporangia. So far cross inoculations with zoospores, and sporangial suspensions on *Agrostis alba, Phleum pratense, Dactylis glomerata, Euchloena mexicana* and *zea mays* proved unsuccessful. The first four grasses which are naturally associated with *Agropyron repens* are free from infection in the field. These two facts suggest that the parasite is obligate on *Agropyron repens*. The possibility of the occurence of physiologic races should not be overlooked. Host hypertrophy is common, the infected leaf becoming many times thicker than the normal and often highly distorted and tubular. The hypertrophy is due to the enlargement of the cells.

Rhizomycelium, ephemeral sporangia, and zoospores and the germination of the resting sporangia all resemble those of *Physoderma zeamaydis* occurring on corn. Multiciliate zoospores were noticed in a small percentage of those liberated from the resting sporangia the significance of which cannot be definitely assessed at present. Apparent fusions were noticed but the very small percentage of such fusions cannot be satisfactorily explained at the moment.

Data with regard to certain environmental influences on the germination of the resting sporangia are presented.

Growth-rainfall trend-coefficients shown by six species of hardwoods in Brown County, Indiana. RAY C. FRIESNER, Butler University.—Highest trend-coefficients shown are: *Carya ovata*, May-July; *C. glabra*, May-July, August-July, and June-May; *Acer saccharum*, May-August and May-June; *Liriodendron tulipifera*, July-June; *Fraxinus americana*, April-July; *Sassafras albidum*, none of any significance. Trend-coefficients for all species increase in percentage with increase percentages of rainfall change. Higher trend-coefficients are shown when rainfall decreases only are considered than when increases only are considered. When any individual tree is compared with any other individual tree, the highest percentage of agreement is as likely to be with an individual of a different species as with an individual of the same species. Liriodendron is the only species which shows a higher average percentage of agreements with individuals of its own species than with individuals of other species.

An investigation of the root-stem transition of *Phaseolus coccineus* Willd. GINO V. GRASSI, University of Detroit.—This work consisted of an investigation of the root-stem transition of *Phaseolus coccineus*, Willd., which was found to be completed high in hypocotyl. The first indication of transition from the tetrarch exarch primary root to the endarch stem occurs where parenchyma is differentiated between the cells of the metaxylem arms forming four distinct triangular-shaped groups of protoxylem and metaxylem. Secondly, metaxylem differentiates tangentially so that there are bands of metaxylem alternating with the four transitional bundles. Continuing up the axis, the protoxylem elements of each bundle differentiate as two rows of spiral cells which are formed at right angles to the metaxylem. Eventually these rows are separated by parenchyma, and now each transition bundle consists of two units. At a higher level, the protoxylem points of the bundles mature in a line with the metaxylem elements. Farther up, there is centripetal differentiation of the protoxylem and a centrifugal differentiation of the metaxylem. Ultimately the endarch condition is reached.

The relation of soluble aluminum ions to the common potato scab disease and to the growth of *Actinomyces scabies* in culture. GEORGE A. GRIES, Purdue University.—Common potato scab may be invariably controlled in mineral soils by increasing soil acidity to pH 5.0-5.2. The same procedure often fails to give satisfactory control in muck soils, with cases being recorded in which scab was severe at pH 4.5. Many strains of the causal organism are found which fail to grow below pH 5.0 but others isolated from both muck and mineral soils will grow in culture at pH values of 4.2-4.3. As little as 16 ppm of aluminum added to the culture solution will inhibit the development of these acid-resistant organisms at pH 5.2 and below. There is a close inverse relation between the growth of *Actinomyces scabies* and the solubility of aluminum over a wide pH range. Maximum growth is obtained at pH 6.5-6.8 at which Al is extremely insoluble. Growth is inhibited in more acid solutions in which Al is soluble as the cation and in more alkaline solutions in which the soluble aluminate is present. It is suggested that scab control under field conditions may be related to soluble aluminum rather than to pH *per se*. The results of field experiments will be discussed.

History of forests in the glacial Lake Chicago area. G. K. GUENNEL, Division of Geology, Indiana Department of Conservation.—A fossil pollen study of peat samples from Pinhook and Merrillville bogs was made. The bogs are located at the edge of the Glacial Lake Chicago basin in northwestern Indiana. The results of the pollen analysis showed that the general succession since glacial recession was *Abies-Picea* to *Quercus-Carya*. However, slight modifications of this sequence were recorded. Pinhook bog, located in LaPorte county, disclosed a transitional pine period, whereas Merrillville bog, in Lake county failed to show evidence of such a period between the *Abies-Picea* and *Quercus-Carya* forest types. A striking phenomenon was noted in the Merrillville profile. *Pinus*, according to the quantitative record, became a strong associate of *Quercus-Carya* during the more recent past. This increase in pine pollen in the upper layers of Merrillville bog was due to local, rather than climatic factors. It represents a *Pinus strobus* relic colony, which persisted on the bog mat until 1940, when a fire eliminated all but one tree. From the general succession, as indicated by pollen frequencies, the following deductions as to climatic changes can be made: The cold-moist climate, which fostered *Abies-Picea*, changed to a warm-dry climate which supported the *Quercus-Carya* association.

Effects of various concentrations of 2,4-D on corn seedlings. ROBERT W. HOSHAW, Purdue University.—In the field most varieties of corn are tolerant of 2,4-D in concentrations which can be used for effective weed control. However, in most cases corn is not resistant to higher concentrations of 2,4-D than those recommended for field use. Two yellow dent single hybrids, Wf9 x Hy and Tr x 38-11, were grown in the greenhouse and treated by spraying with the triethanolamine salt of 2,4-D in concentrations ranging from 500 ppm. to 3000 ppm. Ten pots were treated with each concentration. Both pre-emergence and post-emergence methods of application of 2,4-D were used. The pre-emergence application was made immediately following planting, and the post-emergence treatment was made when the corn was between 8 inches and 12 inches high. The effect of the pre-emergence treatment was noticeable as soon as the plants emerged, with the bending most evident in the pots sprayed with the higher concentrations of 2,4-D. Both the coleoptile and the sub-coleoptile internode were excessively elongated. In many cases the coleoptiles elongated to such an extent that the first leaves emerged from them with difficulty. Also many adventitious roots developed in an irregular manner above the soil level. The recovery of seedlings from the pre-emergence treatment was remarkable during a period of 10 days following emergence. The plants which were subjected to a post-emergence spray treatment showed evidence of bending within 24 hours and by the fifth or sixth day bending was at a maximum. At the higher concentrations the lodging appeared to be permanent and some of the stems showed evidence of breaking. The higher concentrations of 2,4-D greatly reduced plant height and decreased the overall vigor of the plants.

Effects of butyl ester of 2,4-D on some algae. J. DONALD LA CROIX, University of Detroit.—Controlled laboratory experiments on four species of algae, three of which were algal nuisances, were carried out using the butyl ester of 2,4-D as the herbicide. *Cladophora crispata* (Roth)

Kutz., and *Hydrodictyon reticulatum* (L) Lagerh. were killed in a 2,4-D concentration of two hundred ppm. and were definitely inhibited in one hundred ppm. The alga, *Phormidium ambiguum* Gom., was unaffected by one thousand ppm. 2,4-D and lower concentrations. The growth of the flagellate, *Euglena viridis* Ehr. was checked in all concentrations, but the higher dilutions had a greater effect. However, two hundred ppm., the minimum concentration required to kill the algae in this case, has been known to be lethal to fish and other aquatic organisms. It should be remembered that concentrations employed in controlled laboratory experiments may be less effective in ponds, but the laboratory findings should indicate the general trend of field experiments. The present cost of the chemical is so great that its general use will undoubtedly be limited. It is estimated that at the effective concentration of two hundred ppm. of the butyl ester of 2,4-D, the cost would well exceed $850 per acre foot. However, other means such as serial applications of such a dilution to a floating algal mat might prove more feasible. Rotifers and ciliates were destroyed in a concentration of two hundred ppm. while snails were killed in a concentration of nine hundred ppm.

An ecological study of the relationship between direction of slope, elevation and forest cover in Brown County, Indiana. CARL R. MCQUEENEY, Butler University.—During the winter of 1948-49, the forest cover on four slopes facing north, south, east, and west respectively, were studied quantitatively by the quadrat method. Each slope was divided into upper and lower elevations. The four stands on the lower elevation level proved to have a different phytosociological complex than the corresponding stands on the upper elevation level. The forest cover of the area, as a whole, was dominated by *Acer saccharum*[1], *Fagus grandifolia, Quercus alba, Q. borealis v. maxima,* and *Q. velutina* with *Acer rubrum* and two species of *Carya* playing a secondary part. Each individual stand was dominated by a combination of these species. The north facing slope was dominated by a mixture of species with *Acer saccharum,* and *Fagus grandifolia* controlling the lower elevation and *Acer saccharum, Fagus grandifolia, Quercus alba,* and *Q. borealis v. maxima* sharing the upper elevation. On the south facing, *Fagus grandifolia* dominated the lower elevation with *Acer rubrum, A. saccharum, Carya ovata* and *Quercus velutina* playing an important part in the crown cover. The upper elevation of this slope was controlled almost exclusively by *Quercus alba* and *Q. velutina. Acer saccharum, Fagus grandifolia, Quercus alba,* and *Q. velutina* shared dominance on the lower elevation of the east facing slope while *Quercus alba, Q. velutina,* and to some extent *Carya glabra,* dominated the upper elevation. The west facing slope was dominated by *Fagus grandifolia, Quercus alba,* and *Q. borealis v. maxima* on the lower elevation and *Fagus grandifolia, Quercus alba,* and *Q. velutina* on the upper elevation. *Acer saccharum* and *Fagus grandifolia* were in all cases less prominent in the upper elevation and almost completely absent on the latter elevation of the South and East facing slopes. On these two slopes, *Acer saccharum* dropped out rather abruptly at 48 ft. above the valley floor. *Quercus* was, on the whole, more prominent in the upper elevations though important in all stands and *Carya* apparently preferred a habitat which was more xerophytic than that best suited to *Acer-Fagus* and less xerophytic than that best suited to *Quercus alba.*

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[1] *Acer saccharum* includes *Acer nigrum.*

The effect of precipitation on the annual ring growth in three species of trees from Brown County, Indiana. CHESTER W. MILLER, Butler University.—An attempt was made in the late fall and early winter of 1948 to ascertain the relationship between the precipitation and annual ring growth of three species of deciduous trees from Brown County, Indiana; also, to determine which area of the tree, i.e., the top area or the bottom area, gives the highest percentage of agreement between growth and rainfall. 23 different month combination rainfall periods were chosen. *Fraxinus americana* shows highest growth-rainfall trend coefficients for the rainfall periods May-August and June-August; *Quercus alba* for the periods June-August and May-August; and *Quercus velutina* for the periods June-July and June-August. With but few exceptions, growth-rainfall trend coefficients increased with increase in degree of rainfall change. When annual growth of individuals of each species and of different species is compared, the highest percentage of agreement is shown between individuals of the same species except in *Quercus velutina. Q. velutina* shows higher average agreement with *Q. alba* than amongst individuals of its own species. *Fraxinus americana* shows higher growth-rainfall trend coefficients when decreases only in rainfall are considered. The same is true for *Quercus alba* except in the case of 40% or greater rainfall changes. *Quercus velutina* shows higher growth-rainfall trend coefficients when increases only are considered in rainfall than when decreases only are considered when comparison is based upon lower degrees of rainfall change, but the reverse is true when comparison is based upon higher degrees of rainfall change. The average trend coefficients between growth in the top area and the bottom area of the same trees of *Quercus velutina* is 82% while the average for *Quercus alba* is 80%. In both *Quercus velutina* and *Quercus alba,* the top areas give higher growth-rainfall trend coefficients than do the bottom areas. This would appear to indicate that annual growth in the top areas of these species are more sensitive to rainfall changes than annual growth in the bottom areas. (To be published in the Butler University Botanical Studies 9 (17). 1950.)

The effect of sap-removal for syrup-making upon radial growth in sugar maple. CHESTER W. MILLER, Butler University.—Annual growth data of *Acer saccharum* is given for all the sections studied; the oldest dating to the year 1710. This data is presented because the trees offer growth data covering a longer period of time than has previously been reported in any Indiana studies. Sugar maple shows highest growth-rainfall trend coefficient for the rainfall period June-July. This would appear to indicate that the annual radial growth is more sensitive to rainfall during the early summer months. The removal of sap from a sugar maple tree has a definite retarding effect upon the radial growth. The average yearly radial growth for fourteen years prior to the year following cessation of tapping is 0.8 mm. while the average yearly radial growth ten years towards the center of the tree from the innermost limit of the spilehole is 1.8 mm. The year following cessation of tapping shows the maximum amount of radial growth attained in any one year. The annual growth then grades towards the normal ring size over a period of five years. (To be published in the Butler University Botanical Studies 9 (20). 1950.)

The botanists of India and Pakistan. C. M. PALMER, Butler University.—During a two year period, beginning in the summer of 1947, spent in India and Pakistan, the writer had opportunities of meeting a considerable number of botanists and other plant scientists in the educational and research institutions. Photographs of a number of the workers and of the science buildings were taken. The scientists are facing a different situation as the new independent Indian and Pakistan governments strive to increase facilities for scientific work, particularly for practical research and for opportunities for education for all the best qualified students. Several of the scientists have done research which has received worldwide recognition. They were exceedingly cordial and cooperative and were anxious to have additional contacts with scientists in America and elsewhere.

Indiana Plant Distribution Records, X. 1949

Genera are listed in the order used in Deam's Flora and species are given alphabetically within the genera. Symbols following the county in which specimens were collected indicate the herbaria in which confirming specimens have been deposited. Entities new for the state are given in bold face followed by literature references and name of the collector.

The specimens listed below have been collected by the following collectors: Ball State Teachers College (BS): Mrs. Marian Rector; Butler University (B): C. M. Ek, Charles C. Deam, R. C. Friesner, V. O. Graham, Johanna Jones, Jack McCormack, Chester Miller, J. E. Potzger, Kenneth Shockley, and Floyd A. Swink; Chicago Natural History Museum (F): Howard Benke and Floyd A. Swink; Deam Herbarium (D): Charles C. Deam, Ray C. Friesner, and Ralph Kriebel; DePauw University (DP): Elmer E. Callaway, R. C. Friesner, D. Smith, and Winona H. Welch; University of Florida (Fl): C. M. Ek; Gray Herbarium (G): C. C. Deam, Howard Benke, and Ralph Kriebel; Indiana University (IU): C. J. Avers, Charles B. Heiser, Jr., Vernon Helmen, Gladys Price, Dale Smith, Paul Weatherwax, and Winona H. Welch; Huntington College (Hu): Fred Loew; Missouri Botanical Garden (Mo): Churchill; New York Botanical Garden (NY): C. M. Ek and R. C. Friesner; University of Texas (Tex): R. C. Friesner; U. S. National Herbarium (N): C. C. Deam and W. S. Blatchley.

The committee maintains a card file showing published distribution of each species within the state. Botanical workers needing such information may obtain distribution maps of any species recorded in the Flora, or subsequently added in these reports, by requesting same from the secretary of this committee.

Species

Polystichum acrostichoides, Kosciusko (B). *Camptosorus rhizophyllus*, Daviess (B). X *Asplenosorus ebenoides*, Monroe (IU). *Anacharis canadensis*, Putnam (DP). *Bromus commutatus*, Daviess (B). *B. kalmii*, Huntington (Hu). *B. latiglumis*, Orange (B). *B. secalinus*, Daviess (B). Huntington (Hu). *B. tectorum*, Daviess (B). *Vulpia octoflora* v. *tenella*, Daviess (B). *Poa annua*, Hendricks (B). *Elymus riparius*, Huntington (Hu). *E. virginicus*, Orange (B). *Lolium perenne*, Huntington (Hu), Elkhart (D). *Sphenopholis obtusata*, Daviess (B). *Danthonia spicata*, Daviess (B). *Digitaria ischaemum*, Ripley (B).

Panicum clandestinum, Daviess (B). *P. commutatum*, Daviess (B), Putnam (B). *P. flexile*, Kosciusko (B). *P. linearifolium*, Orange (B), Putnam (B). *P. stipitatum*, Clark (B). *P. virgatum*, Jay (D). *Setaria* *faberi,* Vermillion (B). *Andropogon gerardi,* Jay (D). *Eleocharis engelmanni,* Huntington (Hu). *Carex crus-corvi,* Huntington (Hu). *C. davidsii,* Huntington (Hu). *C. hystricina,* Huntington (Hu). *C. interior,* Huntington (Hu). *C. tribuloides,* Huntington (Hu). *C. typhina,* Huntington (Hu). *Arisaema atrorubens* f. *zebrina,* Jefferson (D,B). *Juncus effusus* v. *solutus,* Huntington (Hu). *J. interior,* Huntington (Hu).

Allium tricoccum, Fulton (B). *A. vineale,* Cass (B), Orange (B). *Trillium grandiflorum,* Franklin (B,D,DP). *Smilax glauca* v. *genuina,* Orange (B). *Orchis spectabilis,* Henry (BS). *Liparis liliifolia,* Lagrange (B). *Aplectrum hyemale,* Henry (BS). *Saururus cernuus,* Madison (B). *Populus deltoides,* Madison (B). *Salix alba,* Jay (D). *S.a.* v. *vitellina,* Kosciusko (B). *S. candida,* Jasper (B). *S. fragilis,* Huntington (Hu). *S. glaucophylla,* Carroll (B), Fulton (B). *S. gracilis* v. *textoris,* Carroll (B), Kosciusko (B). *S. humilis,* Orange (B). *S. interior,* Carroll (B). *S. lucida,* Kosciusko (B). *S. nigra,* Union (B). *S. pedicellaris* v. *hypoglauca,* Carroll (B). *S. rigida,* Marion (B), Union (B). *S. sericea,* Huntington (Hu).

Carya cordiformis, De Kalb (D), Elkhart (D). *C. ovata,* Marshall (D). *C. tomentosa,* Brown (B), Marshall (D). *Ostrya virginiana,* Perry (D). *Quercus bicolor,* Jay (D). *Q. borealis* v. *maxima,* Adams (D). *Q. macrocarpa,* Jay (D), Warren (B). *Q. palustris,* Adams (D), Perry (D). *Ulmus alata,* Daviess (B). *Celtis pumila,* Orange (B). *Morus rubra,* Randolph (D). *Humulus americana,* Jay (D). *Urtica dioica* v. *procera,* Madison (B). *Rumex acetosella,* Hamilton (B). *R. altissimus,* Delaware (BS). *R. obtusifolius,* Delaware (BS). *R. orbiculatus,* Fulton (B). *Polygonum erectum,* Madison (B). *P. hydropiper* v. *projectum,* Fulton (B). *P. hydropiperoides* f. *strigosum,* Hancock (B). *P. lapathi folium,* Marion (B). *P. neglectum,* Fulton (B), Marion (B). *P. pennsylvanicum* v. *laevigatum* f. *pallescens,* Madison (B). *P. persicaria,* Fulton (B), Jay (D). *P. punctatum* v. **confertiflorum** (Meisn.) Fassett. Brittonia 6:377. Kosciusko (B), Marion (B,NY,Tex), Porter (Mo). Collected by R. C. Friesner. *P. punctatum* v. **majus** (Meisn.) Fassett. Brittonia 6:373. Porter (F,G). Collected by Howard Benke. *P. virginianum,* Fulton (B). *Acnida altissima* v. *subnuda,* Morgan (IU).

Cerastium nutans, Huntington (Hu). *C.* **semidecandrum** L. Gray Man. 7 ed. p. 383. Porter (B). Collected by Floyd A. Swink. *C. vulgatum* v. *hirsutum,* Pulaski (D). *Holosteum umbellatum,* Henry (BS). *Arenaria serpyllifolia,* Pulaski (D). *Agrostemma githago,* Elkhart (D), Gibson (IU). *Silene antirrhina,* Delaware (BS), Huntington (Hu). *S. cucubalis,* Huntington (Hu). *Lychnis alba,* Huntington (Hu). *Dianthus armeria,* Gibson (IU), Putnam (B). *Saponaria officinalis,* Delaware (BS), Fulton (B). *Hydrastis canadensis,* Orange (B). *Aquilegia canadensis,* Orange (B). *Anemone quinquefolia* v. *interior,* Putnam (DP,B). *Heptica americana,* Huntington (Hu). *Ranunculus abortivus,* Jay (IU). *Thalictrum dasycarpum,* Warren (B). *T. revolutum,* Orange (B).

Stylophorum diphyllum, Delaware (BS). *Dicentra canadensis,* Delaware (BS). *Lepidium virginicum* v. *typicum,* Adams (BS), Warren (B). *Thlaspi perfoliatum,* Franklin (B,D,DP). *Arabidopsis thaliana,* Huntington (Hu). *Rorippa sylvestris,* Hancock (B). *Nasturtium officinale,* Huntington (Hu). *Armoracea aquatica,* Daviess (B). *Cardamine pennsylvanica,* Huntington (Hu). *Camelina microcarpa,* Delaware (BS), Putnam (DP). *Capsella bursa-pastoris,* Pulaski (D). *Arabis canadensis,* Orange (B). *Erysimum repandum,* Delaware (BS). *Alyssum alyssoides,* Adams (BS). *Sedum acre,* Delaware (BS). *Saxifraga pennsylvanica,* Delaware (BS). *Liquidambar styraciflua,* Greene (B). *Physocarpus opulifolius,* Elkhart (D). *Agrimonia pubescens,* Huntington (Hu).

Cassia fasciculata, Henry (BS). *Medicago lupulina,* Warren (B). *M. sativa,* Delaware (BS). *Melilotus alba,* Warren (B). *M. officinalis,* Orange B, Warren (B). *Trifolium dubium,* La Porte (B,F). *T. pratense,* Clay (B), Elkhart (D). *Desmodium marilandicum,* Greene (B). *D. paniculatum,* Madison (B). *Lespedeza stipulacea,* Greene (B). *Amphicarpa bracteata,* Greene (B). *A. b.* v. *comosa,* Madison (B). *Oxalis stricta,* Hancock (B). *Linum virginianum,* Huntington (Hu). *Polygala sanguinea,* Martin (B). *P. verticillata,* Martin (B), Ripley (B). *Euphorbia commutata,* Orange (B). *E. dentata,* Henry (BS), Jay (D). *Staphylea trifolia,* Delaware (BS). *Acer saccharinum,* Delaware (BS), Randolph (D).

Abutilon theophrasti, Hancock (B). *Malva neglecta,* Henry (BS). *Callirhoe involucrata,* Daviess (IU). *Hibiscus trionum,* Delaware (BS), Madison (B). *Hypericum perforatum,* Warren (B). *Viola papilionacea,* Huntington (Hu). *V. triloba,* Orange (B). *Epilobium coloratum,* Fulton (B). *E. leptophyllum,* Jasper (B). *E. strictum,* Jasper (B). *Oenothera perennis,* Lake (B). *Oe. pycnocarpa,* Delaware (B), Henry (BS). *Gaura biennis,* Delaware (B). *Osmorhiza longistylis,* Lake (B). *O.l.* v. *villicaulis,* Marion (B). *Taenidia integerrima,* Orange (B). *Sium suave,* Fulton (B). *Heracleum lanatum,* Randolph (B). *Nyssa sylvatica* v. *caroliniana,* Orange (B). *N.s.* v. *typica,* Spencer (D). *Cornus florida,* De Kalb (D). *Vaccinium stamineum,* Orange (B).

Samolus parviflorus, Daviess (B). *Lysimachia hybrida,* Martin (B), Warren (B). *L. nummularia,* Delaware (BS). *L. quadrifolia,* Orange (B). *Anagallis arvensis,* Martin (B). *Fraxinus americana,* De Kalb (D), Marshall (D), Perry (D). *F. pennsylvanica,* Huntington (D). *Gentiana andrewsii,* Fulton (B). *Frasera caroliniensis,* Delaware (BS). *Acerates hirtella,* Clay (B). *Asclepias amplexicaulis,* Cass (B). *A. syriaca,* Warren (B). *A. tuberosa* v. *interior,* Martin (B). *Gonobolus obliquus,* Orange (B). *Cuscuta campestris,* Orange (B,DP). *C. gronovii,* Henry (B,DP), Warren (B,DP). *C.g.* v. **latiflora,** Engelm. Mem. Torr. Bot. Cl. 18:173. Jasper (B,DP). Collected by R. C. Friesner. *Convolvulus sepium,* Delaware (BS). *Ipomoea pandurata,* Orange (B). *Ipomopsis rubra,* Jasper (B). *Ellisia nyctelia,* Tippecanoe (B).

Cynoglossum officinale, Randolph (B). *Myosotis scirpoides,* Elkhart (D). *Lithospermum arvense,* Delaware (BS). *Echium vulgare,* Delaware (BS). *Verbena bipinnatifida,* Orange (B). *V. bracteata,* Marion (B). X *V. Engelmannii,* Fulton (B), Greene (B). *V. hastata,* Fulton (B). *V. simplex,* Warren (B). *V. stricta,* Orange (B). *V. urticaefolia,* Fulton (B). *Phyla lanceolata,* Hancock (B). *Trichostemma dichotomum,* Delaware (B). *Agastache nepetoides,* Madison (B). *Prunella vulgaris,* Warren (B). *Lamium amplexicaule,* Delaware (BS). *L. purpureum,* Delaware (BS). *Blephilia ciliata,* Orange (B). *Lycopus virginicus,* Huntington (Hu). *Mentha piperita,* Fulton (B). *Physalis heterophylla,* Delaware (BS). *P. pubescens,* Delaware (BS). *Datura stramonium,* Fulton (B), Huntington (Hu), Jay (D).

Verbascum blattaria, Delaware (BS), Warren (B), Wayne (BS). *V.b.* f. *albiflora,* Wayne (BS). *V. thapsus,* Delaware (BS). *Linaria canadensis,* Cass (B). *Penstemon calycosus,* Warren (B). *Gratiola neglecta,* Whitley (B). **Digitalis lanata** Ehrh. Bailey Man. Cult. Plt. p. 673. Harrison (B,D). Collected by C. C. Deam and Johanna Jones. *Dasistoma macrophylla,* Warren (B). *Aureolaria flava* v. *typica,* Huntington (Hu). *Conopholis americana,* Orange (B). *Epifagus virginiana,* Kosciusko (B). *Plantago virginica,* Hamilton (B). *Galium pilosum,* Orange (B). *G. tinctorium,* Adams (BS). *Viburnum dentatum* v. *deamii,* Huntington (Hu). *V. rufidulum,* Orange (B). *Valerianella olitoria,* Franklin (B,D,DP). *Dipsacus sylvestris,* Delaware (BS). *Specularia perfoliata,* Gibson (IU). *Lobelia cardinalis,* Hancock (B).

Vernonia altissima, Fulton (B). *Eupatorium purpureum,* Madison (B). *Liatris* **aspera** v. **intermedia** (Lunell) Gaiser. Rhodora 48:305. Benton (D,B), Cass (B), Crawford (D), Elkhart (D,B), Harrison (B,G), Jasper (B), Lagrange (D,B,G), Lake (B,D,N,NY), La Porte (B), Marshall (D,G,N), Newton (D,B), Porter (D,Mo,N), Pulaski (B), Starke (B,D,G,NY), Steuben (D,Mo,NY), White (B). *Liatris* **aspera** v. **typica** Gaiser. Rhodora 48:301. Jasper (Fl), Porter (G). *Liatris* **earlei** (Greene) K. Schum. Rhodora 48:336. Harrison (D,N). X *Liatris* **nieuwlandii** (Lunell) Gaiser. Rhodora 48:325. Allen (D,Mo), Cass (B,NY), Kosciusko (D,B,G,N,NY), Lagrange (D,N), Marshall (N), Noble (B,D,G,N), Porter (B,G), Steuben (B,D,G,Mo,N,NY), Warren (D,Mo). *Liatris* **scabra** (Greene) K. Schum. Rhodora 48:316. Brown (D,G), Cass (NY), Clark (D,B), Crawford (D,B), Franklin (B), Harrison (B,D,N), Jackson (G), Kosciusko (B,D), Perry (B), Spencer (B), Sullivan (B), Vigo (D,B,N), Washington (D,B,N). *Liatris* **sphaeroidea** Mx. Rhodora 48:312. Lake (D,G,N), Porter (G,N), Steuben (D,G). X *Liatris* **steelei** Gaiser. Rhodora 48:227. Lake (D,B), Porter (B,D,N).

Solidago canadensis v. *gilvocanescens,* Fulton (B). *S. graminifolia* v. *media,* Kosciusko (B). *S.* **patuliginosa** Friesner. Butler Univ. Bot. Stud. 9:125. Huntington (B,D), Montgomery (B). *Aster cordifolius,* Kosciusko (B). *A. drummondii,* Huntington (Hu). *A. dumosus,* Huntington (Hu). *A. interior,* Kosciusko (B). *A. lateriflorus,* Huntington (Hu), Monroe (IU). *Antennaria plantaginifolia,* Huntington (Hu). *Gnaphalium purpureum,* Orange (B). *Inula helenium,* Huntington (Hu).

Silphium terebinthinaceum v. *pinnatifidum*, Greene (B). *Iva xanthifolia*, Porter (B).

Eclipta prostratus, Hancock (B). *Rudbeckia laciniata*, Jay (D). **Helianthus annuus X. H. petiolaris,** Vigo (IU). Collected by George B. Heiser. *H. decapetalus*, Fulton (B). *H. giganteus*, Lake (B). *H. laetiflorus* v. *rigidus*, Vermillion (B). *H. strumosus*, Harrison (B), Madison (B), Tippecanoe (B), Vermillion (B). *H. tuberosus*, Union (B). *Bidens bipinnata*, Lake (B). *B. vulgata*, Marion (B). *Erechtites hieracifolia*, Fulton (B). *Cirsium arvense* v. *vestitum*, Delaware (BS). *Cacalia muhlenbergii*, Warren (B). *Krigia virginica*, Cass (B). *Sonchus oleraceus*, Warren (B). *Lactuca canadensis* v. *latifolia*, Warren (B). *L. saligna*, Madison (B). *L. scariola*, Jay (D), Madison (B). *L. villosa*, Greene (B).

Additional Species Added to the Deam Herbarium

The following species previously reported in other herbaria have been added to the Deam Herbarium since the last report.

Polypodium polypodioides v. *michauxianum*, Jefferson. *Sphenopholis nitida*, Jefferson. *Setaria lutescens*, Jay. *Ornithogalum umbellatum*, Jefferson. *Smilax herbacea* v. *herbacea*, Jefferson. *S. pulverulenta*, Jefferson. *Hypoxis hirsuta*, Jefferson. *Populus deltoides*, Adams. *Fagus grandifolia*, Huntington, Jefferson. *Quercus alba*, Perry. *Q. imbricaria*, Adams. *Ulmus rubra*, De Kalb. *Cerastium vulgatum* v. *hirsutum*, Elkhart. *Silene antirrhina*, Elkhart. *Ranunculus hispidus*, Jefferson. *Duchesne indica*, Jefferson. *Cercis canadensis*, Randolph. *Desmodium paniculatum*, Huntington. *Oxalis stricta*, Elkhart. *Acer nigrum*, Jefferson. *Daucus carota*, Jay. *Nyssa sylvatica* v. *caroliniana*, Gibson. *Lysimachia ciliata*, Jay. *Stachys tenuifolia*, Randolph.

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The Pteridophytes of the Valparaiso Moraine of Porter County, Indiana

William W. Bloom, Valparaiso University

Porter County, Indiana is rich in species of plants owing to the varied physiography provided by the dune and sandy areas near Lake Michigan in the northern part of the county, to the moraine running through the middle of the county, and to the Kankakee marsh on the south. Of the eighty-two species, varieties, and hybrids of pteridophytes reported for Indiana in Deam's Flora of Indiana (2), forty-three were reported from Porter County. Four additional species have been reported for the county in the Indiana Plant Distribution Records published in the Proceedings of the Indiana Academy of Science (3).

Much of the botanizing done in Porter County has been done in the sand dunes. Because of the popularity of the dunes as a summer resort and the ease with which a wide variety of environments can be studied, many of the reports for the county have been made on the basis of collections in the dune area. The extent of the work done in the dunes and adjacent sandy areas is indicated by the several floras which have appeared, including the floras of the dunes and nearby areas. A few of such published floras are those by Lyon (4, 5), Pepoon (7), and Peattie (6).

The probability that the morainal region of Porter County has not been studied and reported as intensively as the areas to the north is evidenced by the collection during the present study of several species and varieties not previously reported for any part of the county. The following species and varieties collected while this study was made are not included in Deam's Flora (2) or in subsequent reports: *Cystopteris fragilis* (L.) Bernh. var. *protrusa* Weatherby, *Athyrium pycnocarpon* (Spreng.) Tidestr., *Dryopteris spinulosa* var. *fructuosa* (Gilbert) Trudell, *Equisetum arvense* var. *boreale* (Bong.) Rupr., and *Equisetum hyemale* L. var. *affine* (Engelm.) A. A. Eaton.

The geological formation known as the Valparaiso Moraine extends across the middle portion of Porter County and covers a large area, with varied physiography, microclimates, soils, and water relations. This variation in environments has favored the development of a flora rich in species. The greater part of the moraine has been disturbed much more than the dune area.

The most complete geological study of the area is that of W. S. Blatchley (1) published in the 22nd Annual Report of the Department of Geology and Natural Resources of Indiana. The moraine in Porter County consists of about two hundred thirty-five square miles of land

and comprises a band seventeen miles wide on the western border of the county which swings northeast and narrows to seven miles in width at the eastern county line. The entire area is covered with a sheet of drift which is as much as one hundred twenty-five feet thick at Valparaiso. The extent and location of the moraine in Porter County is shown on the map in figure 1.

The richest pteridophyte collections were made in three areas, although a greater part of the moraine was covered. The first is a cut-over mesophytic forest located on the south side of U. S. Highway 6 about three miles east of its junction with Indiana Highway 49. This forest has been ungrazed for about 17 years and is at present a classified forest. The principal tree species in the forest at present are sugar maple (*Acer saccharum*), beech (*Fagus grandifolia*), white oak (*Quercus alba*), black oak (*Q. velutina*), and red maple (*Acer rubrum*). Many physiographic features of the moraine are represented in this forest. The second collecting site is a small beech-maple forest (*Acer saccharum* and *Fagus grandifolia*), cut over, but not recently grazed. It is located about two miles northeast of Valparaiso, just north of the Grand Trunk Railroad and west of Indiana Highway 2. The third area is a small, partially drained tamarack bog along Salt Creek about two miles directly south of the main part of Valparaiso. This bog is unprotected from grazing and may soon cease to be as rich botanically as at present.

Annotated List of Species Collected on the Valparaiso Moraine

1. *Botrychium dissectum* var. *obliquum* (Muhl.) Clute. Three specimens of this fern were observed in the beech-maple forest.

2. *Botrychium virginianum* (L.) Sw., the rattlesnake fern, was one of the more common ferns on the moraine. Many specimens were observed in all three collecting areas, as well as in many other places on the moraine. One specimen measured thirty-two inches from the ground to the tip of the fertile portion of the frond.

3. *Osmunda regalis* L. var. *spectabilis* (Willd.) Gray, the royal fern, was one of the more conspicuous ferns in the wet mucky places in all three areas referred to earlier.

4. *Osmunda Claytoniana* L., the interrupted fern, was one of the more difficult ones to find, but later findings suggest that many of the ferns which were at first glance considered to be the cinnamon fern were actually the interrupted fern without fertile portions on the fronds.

5. *Osmunda cinnamomea* L., the cinnamon fern, was very common in the tamarack bog and on the slopes of the pockets and ridges in the mesophytic forest.

6. *Cystopteris fragilis* (L.) Bernh., the fragile fern, is one of the most common ferns on the moraine. It was found in all three areas referred to, as well as in many widely scattered woods. In many places it was the most common species in the herb layer.

(a). *C.f.* var. *protrusa* Weatherby. One specimen which seems to belong to this variety of the fragile fern was collected. It was found growing on a rotting log in a mucky portion of the beech-maple forest. Since it was the only specimen noted, it may have been an environmental variant of the typical form.

7. *Onoclea sensibilis* L., the sensitive fern, is a very common fern in moist areas. Numerous specimens were seen along roads, in the tamarack bog, in the beech-maple forest, and in wet places generally.

8. *Dryopteris hexagonoptera* (Michx.) C. Chr. Several small clumps of the broad beech fern were found in the higher parts of the beech-maple forest and on the slopes of pockets in the mesophytic forest. Some specimens were thought to belong to the narrow beech fern *(D. Phegopteris)* but the determination is doubtful, so for the present they are being considered variants of the broad beech fern.

9. *Dryopteris Thelypteris* (L.) A. Gray var. *pubescens* (Lawson) A. R. Prince, the marsh fern, was common in very wet places in numerous locations on the moraine. Frequently it was found growing together with the sensitive fern in wet meadows.

10. *Dryopteris cristata* (L.) A. Gray, the crested fern, was found only in the tamarack bog where it was common.

11. *Dryopteris spinulosa* (O. F. Muell.) Watt. This fern is one of the more common ones on the moraine in wet areas. Many clumps were seen in the tamarack bog and in the mesophytic forest. It was less common in the beech-maple forest.

a. *D.s.* var. *fructuosa* (Gilbert). This variety was found in the mesophytic forest in association with the typical form.

12. *Polystichum acrostichoides* (Michx.) Schott., the Christmas fern, was not common. Several small clumps were observed in the mesophytic forest and in the beech-maple forest.

13. *Athyrium pycnocarpon* (Spreng.) Tidestr., the narrow-leaved spleenwort, was found growing extensively in the higher parts of the beech-maple forest. It was usually found growing in association with the silvery spleenwort.

14. *Athyrium thelypteroides* (Michx.) Desv., the silvery spleenwort, was one of the common ferns in the beech-maple forest, occurring in the higher, better drained parts of the forest.

15. *Athyrium angustum* (Willd.) Presl., the lady fern, was found in moist places in the more open parts of the beech-maple forest and the tamarack bog.

(a). *A.a.* var. *elatius* (Link) Butters. This variety was found growing with the typical form.

(b). *A.a.* var. *rubellum* (Gilbert) Butters. This variety was found growing with the typical form.

16. *Adiantum pedatum* L., the maidenhair fern, was found on the slopes of the pockets and ridges of the moraine in the mesophytic forest, but not observed elsewhere.

17. *Pteridium aquilinum* (L.) Kuhn var. *latiusculum* (Desv.) Underw. ex. Heller, the bracken fern, was very common over much of the

moraine, especially along railroad tracks, country roads, and at the edges of some of the forests.

18. *Equisetum arvense* L. This horsetail was found growing along railroads, beside country roads, and in the wet meadows. It was also found in the tamarack bog.

(a). *E.a.* var. *boreale* (Bong.) Rupr. This variety was found growing in moist places in an oak-hickory forest and in the tamarack bog in sites less exposed to the sun than were the sites in which the typical form was common.

19. *Equisetum hyemale* L. var. *affine* (Engelm.) A. A. Eaton. This plant was found growing along the Pennsylvania railroad just east of Valparaiso and on a road fill several miles south of Valparaiso. The plants from the two areas showed considerable variation in size.

20. *Equisetum fluviatile* L., the water horsetail, was found in a wet place along Sager's Road, just south of Valparaiso University and in the tamarack bog. In neither place was it abundant.

The writer wishes to take this opportunity to acknowledge the help he has received in preparing the present study. Dr. Paul D. Voth and Dr. George D. Fuller, both of the University of Chicago, aided in identifying some of the more difficult specimens and made many helpful suggestions. It was impossible for the writer to visit all the herbaria containing specimens from Porter County in order to check such specimens to determine whether any of them had been collected on the moraine. Dr. Charles C. Deam, Dr. R. M. Tryon Jr., Dr. Winona H. Welch, Dr. Paul Weatherwax and Mr. Paul Holle kindly furnished information on the specimens in question.

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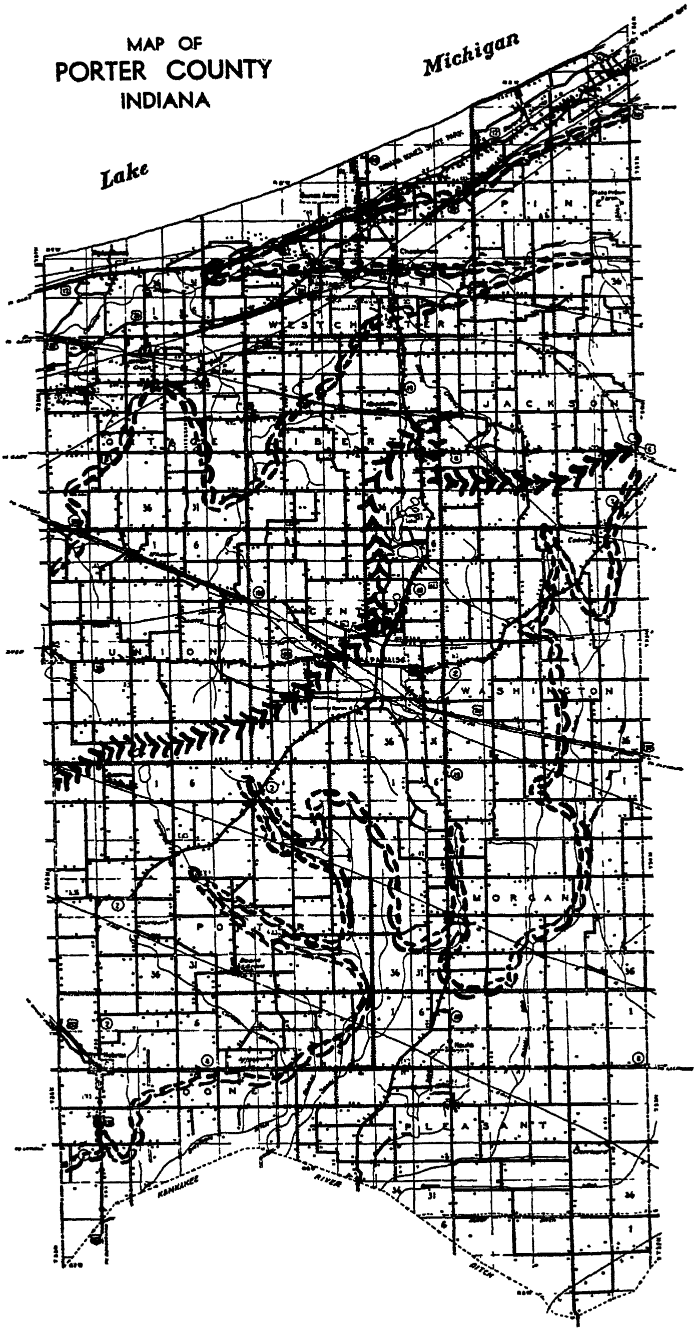

Fig. 1. Map of Porter County, Indiana, showing the borders (dashes) and crest (arrows) of the Valparaiso Moraine.

Higher Fungi of Marion County, Indiana

John O. Cottingham, Indianapolis

We have previously reported 238 species of fleshy, leathery and woody fungi found in Marion County and identified. We are now adding 55 more, bringing the total to 293 species.

Credit should be given to the following persons who assisted me in the search for fungi: Mrs. Arthur H. Beard, Mrs. R. V. Roberts, John C. Tacoma, Alvin Jose, John W. Baumgartner and Homer Knight; also my thanks to Dr. Alexander H. Smith, of the University of Michigan, who kindly identified some specimens that I sent to him.

Agaricaceae

Amamita verna Fr.
A. cothurnata Atkin
Amanitopsis strangulata Fr.
Collybia strictipes Pk.
C. plexipes Fr.
C. myriodophylla Pk.
Cantharellus cinnabarinus Schw.
Clitopilus abortivus B & C
C. caespitosus Pk.
Clitocybe odora Fr.
C. cerussata Fr.
C. cyathiformis Fr.
C.sinopica Fr.
C. albidula Pk.
Cortinarius collinitus Fr.
C. coloratus Pk.
C. armillatus Fr.
Coprinus ovatus Fr.
Crepidotus haerens Pk.
Entoloma clypeatum Fr.
Hebeloma albidulum Pk.
Lepiota alluviinus Pk.
L. miamensis Morg.
Lentinus vulpinus Fr.
Lactarius hygrophoroides B & C
Hygrophorus conicus Fr.
H. psitticinus Fr.
H. roseibrunneus
Mycena polygramma Fr.
M. epipterygia Fr.
Pholiota aeruginosa Pk.
P. marginata Fr.
Pluteus umbrosus Fr.
Russula fragilis Fr.
R. pectinatoides Pk.
Tricholoma alba Schaeff.

Polyporaceae

Daedalia steroides Fr.
Boletus purpureus Fr.
B. castaneus Bull.
B. albellus Pk.
B. chrysenteron Fr.
B. pachypus Fr.
B. Frostii Russell
B. indecisus Pk.
Polyporus dichrous Fr.
Strobilomyces strobilaceus Berk.

Lycoperdaceae

Astreus Hygrometricus Morg.
Cyathus stercoreus Schw.
Dictyophora duplicata Bosc.

Tremellaceae

Tremella epigaea B & B

Hydnaceae

Hydnum nigrum Fr.
H. imbricatum L.

Ascomycetes

Verpa conica Swartz.
Daldinia vernicosa Schw.
Patella umbrosum Seav.

Natural Regeneration from Planted Conifers in Indiana

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Early tree planting in Indiana consisted mostly of farmstead planting of such species as White pine *(Pinus Strobus)*, Norway spruce *(Picea excelsa)*, Austrian pine *(Pinus austriaca)*, red cedar *(Juniperus virginiana)*, and Virginia pine *(Pinus virginiana)*. The early settlers in Indiana often brought with them a few trees for homestead, school ground and cemetery planting. From some of these planted trees natural regeneration occurred which invaded adjacent areas and in some cases these conifers appeared to be native to the locality.

Land use practices have caused many thousands of acres of former agricultural land to revert back naturally to forest cover. On other areas soil conditions have been so greatly changed that tree planting is necessary to establish a stand of forest trees.

Investigations of forest tree planting began in Indiana about 1904 when the first experimental plots were established on the "Forest Preserve", now the Clark State Forest, near Henryville in Clark County, Indiana. Since that time tree planting has continued and to-day there are approximately 15,000 acres of coniferous forest plantations that have become established and if properly managed will produce forest products.

That planted conifers were capable of producing viable seed which led to natural regeneration becoming established adjacent to the seed producing trees was first noted in 1928. An old Scotch pine windbreak growing on a sandy soil in White County had produced seed crops from which seedlings became established on the area adjacent to the windbreak. Two other Scotch pine plantings in Pulaski County had also produced viable seed which resulted in the establishment of Scotch pine regeneration on both sandy and muck soils. Later during a period when intensive studies were made of several hundred forest plantations throughout the State, it was observed that natural regeneration from planted trees was frequently encountered though few such observations had been reported.

In order to show what has taken place as well as what is taking place, a few specific examples of natural regeneration from planted conifers will be given.

White Pine *(Pinus Strobus)*

This species has been used for tree planting in Indiana for a good many years. It is well suited for planting on the better sites. Some of the established plantations of white pine will yield valuable forest product.

Viable seed is produced when planted trees are about 15 to 20 years old. One of the oldest white pine plantings from which natural regeneration has resulted is located on the Clark State Forest. The trees were planted in 1912. Survival has been good and at the present time the 37 year old trees are from 6 to 16 inches d.b.h. and 60 to 90 feet in height. Seedlings have become temporarily established both under the planted trees as well as on adjacent areas. Although the growth of the seedlings has been slow it is interesting to note that they have persisted for several years. Seedlings which were 2 to 4 inches in height when marked 6 years ago still persist but show very little growth.

Viable seed has been produced in several other white pine plantations on the Clark State Forest that are now 25 years old. Regeneration consists of white pine seedlings from one to 5 years old.

The most unusual example of white pine regeneration on a unfavorable site occurs on an area of stripped coal lands in Greene and Sullivan Counties. There white pine trees planted on the spoil banks in 1927-28 have produced viable seed. From these seeds regeneration has become established. The naturally seeded trees are from one to 7 years old and are found adjacent to the parent trees and extending out from the seed trees about 300 feet. These naturally seeded white pine appear to be thrifty and show promise of developing into trees of food form.

These examples and similar ones that have been observed indicate that natural seeding of white pine can be expected from planted trees.

Red pine *(Pinus resinosa)*

Although this species has been planted very extensively in Indiana most of the plantings are less than 20 years old. Natural regeneration of this species was first observed on the strip coal lands. Like white pine, viable seed is produced on 15-20 year old trees. The trees which produced the seed from which natural regeneration developed were planted on the spoil banks in 1926-27. The planted trees that became established now occur in small groups with seed trees 4 to 8 inches d.b.h. and 25 to 35 feet in height. Adjacent to several of these groups of seed trees red pine seedlings have established. They vary in size from 2 inches to 5 feet in height and are from 1 to 7 years old. Height growth of the naturally grown seedlings is like that of planted trees. The red pine planting is located in Sullivan County which is several hundred miles south of the natural range of red pine and therefore natural regeneration would ordinarily not have been anticipated. On a few other sites, particularly on the sandy soils in Northern Indiana, red pine seed trees have produced viable seed. The seedlings originating from these seed trees are from one to four years old but not as well developed as those occurring on the spoil banks.

Since red pine is one of the best trees for reforestation purposes in Indiana these examples of natural regeneration from planted trees are encouraging. It indicates that the species may eventually form a small component part of the mixed hardwood forest in some parts of Indiana.

Jack pine *(Pinus banksiana)*

This species has been and continues to be used very extensively for planting in all parts of Indiana. It makes a quick initial height growth and begins to bear viable seed when planted trees are 5 years old. Frequent seed crops are produced even though most of the jack pine stands are less than 20 years old. Natural regeneration from planted trees is encountered on many sites ranging from the light sandy soils to the heavy clay soils. There are numerous places where natural seeding of jack pine can be observed and of these, two will be described.

The most unusual case of natural regeneration of jack pine has occurred in southeastern Indiana in Jennings county. Trees planted on a heavy clay soil in 1932 were destroyed by fire in October 1940. The fire burned over about seven acres and only a few trees survived the fire. Natural regeneration became established in the spring of 1941 and it now covers almost the entire seven acres. These naturally seeded jack pine are from 5 to 15 feet in height and density of stocking varies from 2,000 to 15,000 trees per acre.

The naturally seeded trees show growth characteristics similar to that of planted trees and the trees are generally straight-boled.

On the stripped coal lands natural regeneration of jack pine is frequently encountered. The natural regeneration that has originated from seed produced by planted jack pine varies from seedlings to trees 15 feet in height. In one case a 15 year old group of jack pine has produced viable seed from which seedlings have grown and have invaded an adjacent area which formerly supported an orchard. Natural seeding has gradually extended out from the parent trees to a distance of approximately 1,000 feet.

Although many similar examples could be given it appears evident that jack pine natural regeneration from planted trees can be expected wherever land adjacent to seed sources is not used for agriculture and where fire and grazing have been excluded.

Scotch pine *(Pinus sylvestris)*

Recent studies have shown that the use of Scotch pine should be confined to Christmas tree and windbreak plantings. However, it has been planted in all parts of Indiana and natural regeneration from planted trees is commonly found. It appears that of all the species that have been used for planting in Indiana, excepting Virginia pine, that natural regeneration of Scotch pine was observed earlier than that of other species of pine. It does not begin to produce viable seed until trees are from 15 to 20 years old. Regeneration from seed produced by individual trees or blocks of seed trees is usually scattered and apparently seedlings do not quickly invade adjacent areas. Regeneration can be found on all sites from the sandy areas of Northern Indiana to the heavier clay soils of Southern Indiana. Like jack pine, natural regeneration is commonly encountered on the spoil banks. Scotch pine trees ranging from small seedlings to 15 foot trees have become established, from seed produced by planted trees.[1] However, dense stands like those described for jack pine have not been observed.

Pitch pine *(Pinus rigida)*

Although pitch pine plantings on non-agricultural lands occupy a relatively small acreage compared to red pine, jack pine or white pine, natural regeneration has occurred. Like jack pine, more naturally seeded trees can be found growing on the spoil banks than any other areas in Indiana. On lands in Warrick County, Lawrence County, Jennings County and Clark County trees from seed produced by planted pitch pines have become established. The largest trees that have been observed are approximately 5 feet in height. Most of the pitch pine seedlings are less than 5 feet in height and occur as scattered trees.

Japanese red pine *(Pinus densiflora)*

There are only a few small plantings of this species but in four different places natural regeneration has been observed. On the Clark State Forest naturally seeded trees ranging in size from 4 inches to 6 feet in height can be found growing in mixture with naturally seeded white pine, jack pine and Virginia pine. It has also invaded a 36 year old plantation of sycamore on the Clark State Forest and here the Japanese red pine trees are from 1 to 7 feet in height. Stand density of the pine varies from a few trees per acre to 1,000 but most of the seedlings occur in small groups or as scattered individual trees. The planted trees from which seed has come are rapidly dying out while some of the largest of the naturally seeded trees have already produced a few cones. It is doubtful whether enough trees of this species will persist and consequently competition from other pines and hardwoods will eventually eliminate the Japanese red pine. It is not a suitable tree for planting in Indiana and its use was discontinued 10-15 years ago.

Virginia pine *(Pinus virginiana)*

Until 1935 this species had not been generally used for reforestation purposes in Indiana. Natural regeneration has come from planted trees of this species where it has been used for farmstead, school ground and church yard planting. Some of these planted trees have been observed and reports of natural regeneration of Virginia pine have been published. These examples are not included and only those cases are considered where the pine has been planted on non-agricultural land as part of a reforestation project.

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[1] DenUyl, Daniel. 1948. Forest plantations, their establishment, growth, and management. Purdue University Agr. Expt. Sta. Circular 331.

Natural regeneration from forest plantations of this species has been found in five places, namely, 2 plantations in Lawrence County—1 in Jackson County and one in Tippecanoe County and one in Washington County. Most of these planted trees from which seed has originated are less than 12 years old. Natural regeneration ranges from small seedlings to trees 6 feet in height. These occur as scattered individual trees adjacent to the parent trees.

This species has been planted in many parts of Indiana during the past 10 years. Its early seeding habit indicates that natural regeneration from planted trees will be frequently observed during the next few years.

Summary

Case histories of natural regeneration of seven different conifers that have been used for reforestation in Indiana have been described. It is evident that planted trees of jack pine, Virginia pine, red pine and white pine and to a lesser extent Scotch pine, will produce viable seed from which under favorable conditions seedlings will become established. Protection from fire and domestic livestock grazing of adjacent non-agricultural land will often result in the establishment of pine regeneration from planted trees. Some of these naturally seeded trees may survive hardwood competition and occur as individual pines in a mixed hardwood stand.

A Comparison of the Flora as a Whole and the Weed Flora of Indiana as to Polyploidy and Growth Habits

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Cytological surveys of floras as a whole have become increasingly popular in recent years, but few accounts have appeared which have placed particular emphasis upon weedy floras. With T. W. Whitaker (9), I recently surveyed the chromosome numbers and growth habits of the most wide-spread weeds of California. The conclusion reached was that, with certain exceptions, polyploidy is not a significant factor in the formation of weeds. In the study of the weeds of California, no comparison was made between the amount of polyploidy in the flora as a whole and that of the weed flora, and in the present paper such a comparison is made.

Procedure

Deam's "Flora" (4) has been used throughout this study for the species found in the Indiana flora. Chromosome numbers have been taken from the lists of Gaiser, Tischler, Maude, Rutland, and Darlington and Janaki-Ammal, and from the more recent works of Bowden (2) and Löve and Löve (10). Special monographs were consulted for a number of families and genera, chief among them being those by Senn (17), Wahl (21), Gregory (6), Perry (14), Myers (13), and Brown (3). Information regarding the growth habits have been secured for the most part from MacDonald's (11) special study. Species designated as weeds have been determined from the notes given in Deam's "Flora," from Muenscher's (12) "Weeds," and from the author's own field experience.[1] Those weeds which have a purely local distribution or are known only from a very few localities have not been included, and hybrids have been also omitted from the computations. The methods of scoring follow the procedure used in the study of the weeds of California (Heiser and Whitaker, 9). This report is obviously a compilation.

Results

The principal results of the present survey are given in Tables I, II, and III. Of a total of 2073 species given in Deam's "Flora," counts have been located for 867 (42%), excluding those introduced species

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[1] The definition that has been followed here is that weeds are plants which are adapted to areas which have been disturbed in some way by man (or his domestic animals) but are not intentionally cultivated by him. (Heiser 8).

TABLE I. Polyploidy and Growth Habit of the Indiana Flora

	Total No. of Species	% of total flora
woody perennials	300	14.76
herbaceous perennials	1323	65.11
annuals (& biennials)	409	20.13
diploids	464	51.61
polyploids	435	48.39
diploid annuals	102	11.35
diploid perennials	362	40.27
polyploid annuals	76	8.45
polyploid perennials	359	39.93
woody diploids	110	64.71
woody polyploids	60	35.29
herbaceous perennial diploids	253	45.83
herbaceous perennial polyploids	299	54.17
species with counts available	867*	41.82
species with growth habits available	2032	98.02

* Some species are reported with two counts.

of limited distribution and escapes from cultivation. Growth habits have been tabulated for 2032 (98%) species. Of these, 409 (20%) are annuals; 1623 (80%) are perennials. In the latter group there are 1323 herbaceous species as opposed to 300 woody species (Table I).

For the flora as a whole, including both weedy and non-weedy plants, 52% of the species are diploid (Table I). It has been estimated that approximately half of the species of angiosperms are polyploids and the flora of Indiana does not fall far short of this mark. The amount of polyploidy in the Indiana flora is slightly less than that reported for the Scandanavian countries (see Löve and Löve, 10).

If the diploids and polyploids are broken down into annual and perennial categories, one finds a total of approximately 11% diploid annuals, 40% diploid perennials, 8% polyploid annuals, and 40% polyploid perennials. These figures would tend to suggest that among the angiosperms of Indiana, polyploidy is not significantly higher among the perennials than among the annuals. As one would expect, the perennials significantly outnumber the annuals at both the diploid and polyploid level.

Slight differences between diploidy and polyploidy are evident, if the perennial species for which chromosome counts are available are subdivided into herbaceous and woody categories. Thirty-five per cent of the woody species are polyploid as compared to 54% for the herbaceous perennial species. Approximately 43% of the annuals are polyploid. These figures lend support to Stebbins' (19) contention that the tendency toward polyploidy in the angiosperms is more pronounced in the herbaceous perennials than in woody plants and annuals.

The total number of species considered as weeds in the present investigation is 287. Fifty-seven per cent of these weedy species are annuals in contrast to 23% annuals for the herbaceous flora as a whole (Table II). This result might be interpreted as indicating that there is a greater tendency for annuals than for perennials to behave as weeds. This tendency, except for specialized areas, may well be a general phenomenon and not applicable only to the Indiana flora. The number of annual weeds in the California flora is even more pronounced. For the 175 weeds of California analyzed as to chromosome number, 56% were annuals (Heiser and Whitaker, 9). If, however, all of the species in the "Weeds of California" (Robbins, Bellue, and Ball, 15) are included, it is found that over 80% of the species are annuals. However, in the California flora, no comparison between the weedy annuals and the annuals in the flora as a whole has yet been made; the annuals of California may be considerably more numerous than for the Indiana flora because of the great number of desert annuals.

TABLE II. Polyploidy and Growth Habit of Indiana Weeds

	Total No. of Species	% of total flora
perennials	123	42.86
annuals (& biennials)	164	57.14
diploids	135	54.66
polyploids	112	45.34
diploid annuals	81	32.79
diploid perennials	54	21.86
polyploid annuals	56	22.67
polyploid perennials	56	22.67
species with counts available	232*	80.84
species with growth habits available	287	100.00

* Some species are reported with two counts.

The total number of introduced species among the 287 weeds of Indiana treated in the present work is 53%, the great majority of the aliens coming from Europe or Eurasia. It is of interest to note that Blatchley, in 1912, records 51% aliens among the 150 weeds "most harmful to the farmers" of Indiana. Muenscher (12) analyzed 500 weeds of the northern United States and found that 61% of the species were introduced. The reason for the large number of introduced weeds in the eastern United States has been discussed by Gray (5).

Chromosome numbers have been located for 232 of the weedy species, of which 55% are found to be diploid (Table II). The percentage of polyploidy among the weeds (45%) is actually slightly lower than that for the flora as a whole (48%), but this difference is probably not significant. The data presented here would certainly seem to verify the conclusion that polyploidy, *per se*, has not been an important factor in the formation of weeds. This last statement, however, should not be taken to mean that polyploidy may not have been of importance in the development of some weedy species.

When the weeds are subdivided into the various categories of growth habit and ploidy, the greatest number are found in the diploid annual group (33%) and the remaining species are about evenly distributed among the other categories (22% diploid perennials, 23% polyploid annuals, and 23% polyploid perennials). These figures are similar to those for the California weeds.

Although it does not seem desirable to make detailed comparisons of the weedy and the non-weedy species, for many of the native species may fall into both classes, the following figures are of interest: 79% of all the diploid annuals and 74% of all the polyploid annuals are weeds, whereas only 21% of the diploid perennials and 19% of the polyploid perennials are weeds; very few woody species behave as weeds and hence the woody members have been excluded from the perennial groups for the above percentages. The above figures indicate that the diploid annuals are the most successful weeds in Indiana and are followed closely by the polyploid annuals.

A comparison of the total number of introduced and native weeds in the various categories of growth habits and ploidy is shown in Table III. There are approximately equal numbers of native species in the four different categories, but among the introduced species by far the greatest number is found in the diploid annual category. The great preponderance of introduced diploid annuals among the weeds of Indiana seems to indicate that as a class they are the most successful weeds.

Discussion

It is worth while to list some of the reasons why some of the conclusions reached above, particularly those regarding polyploidy, are of a very tentative nature. (1) Not all of the species for which chromosome counts are reported can be scored definitely as diploids or polyploids since the basic number in many genera has not been established with certainty. (2) Two counts are recorded for some "species" and scoring these in both diploid and polyploid categories may introduce some error. However, probably no greater accuracy would be gained by giving such species one-half value in each category or by omitting them entirely. At least one species—*Claytonia virginica*—(Heiser, unpubl.) is known to have both diploid and tetraploid forms in Indiana. This may well be true of other species. (3) Many of the chromosome counts used in preparing this report may be inaccurate for Indiana materials. Only a small fraction of the counts have been made or verified from the Indiana flora, and, moreover, a large portion have not even been made upon North American material. (4) Inaccurate taxonomic determinations of some of the early workers or various other nomenclatorial difficulties may have led to mistakes in the present tabulation. (5) As may be seen from Table I, less than half of the species represented in Indiana are reported with chromosome counts, and the conclusions regarding the polyploidy in the flora as a whole may have to be altered somewhat when our knowledge becomes more complete. However, over 80% of the species regarded as weeds (Table II) have known chromosome counts, so that the figures for them are somewhat more reliable. Since chromosome numbers of so few of the non-weedy species are known, comparisons have been made between the whole flora (including the weeds) and the weeds alone. This is also necessary because many of the native species may behave both as weeds and non-weeds. (6) McDonald's (11) list of growth habits has been found to contain some mistakes, and additional ones may have been overlooked. (7) Exactly what species to admit among the weeds has offered difficulties. Opinions as to what constitutes a weed vary greatly and the likelihood of two people compiling exactly the same list of weeds for the Indiana flora is remote.

With the foregoing limitations in mind, however, I would still be inclined to conclude that apparently polyploidy has had no greater effect in producing successful weeds than it has had in producing successful wild species, and, secondly, that as a class the diploid annuals seem to be particularly successful as weeds. These studies fail to corroborate Gustafsson's (7) conclusion that presumably diploid predecessors of weeds were not able to create successful "(agro-)ecotypes."

The annual species, both diploid and polyploid, seem to have provided us with a greater number of weeds than the perennials. Bews (1) has stated that annuals are characteristic of the most adverse conditions and points out that they are particularly suited to habitats brought about by man's disturbance, but he advances no reasons to account for these characteristics. Salisbury (16, p. 25) has suggested that "in so far as the small seed and annual habit go together, they are both features which probably alike have survival value in habitats which are subject to recurrent adverse conditions." The total seed output of the annuals might appear to be an important factor in the success of annuals under such conditions, but Salisbury (16, p. 231) in a comparison of annual and perennial species of the same genus, finds that the latter have the higher seed output. A more rapid reproduction rate (Heiser and Whitaker, 9) and the ability to produce seed under adverse conditions (see Muenscher, 12, p. 4) are probably more effective than is total seed output. Wulff (22) drawing particularly from the work of Thellung, has suggested that there is an involuntary selection for the annual habit among weeds through the annual plowing of fields.

The small seed, a rapid reproduction rate, the ability to seed under adverse conditions, and involuntary selection by man have probably been responsible for the great proportion of annuals among weeds; and polyploidy apparently has not played an important role. As Soó (18) has pointed out, gene content is more important than chromosome number in the ecological adaptation of plants. The future approach to the study of the origin and evolution of weeds should probably be through combined ecological and genetical studies rather than a mere analysis of chromosome numbers.

Summary

A compilation of chromosome numbers and growth habits of Indiana plants has been undertaken, and the principal results in regard to polyploidy and growth habits of the flora as a whole are presented in Table 1. An analysis of polyploidy and growth habits in weedy species has also been attempted and the results are shown in Tables 2 and 3. It is pointed out that many of the conclusions drawn must be of a tentative nature, but it is apparent that polyploidy has been of no greater importance in the formation of weeds than it has in the formation of wild species and that the annual species, particularly diploid annuals, are the most successful weeds.

TABLE III. A Comparison of the Polyploidy and Growth Habits of the Native and Introduced Weeds of Indiana

	NATIVE		INTRODUCED	
	Total No. of species	% of total flora	Total No. of species	% of total flora
diploid annuals	22	24.18	59	37.82
diploid perennials	26	28.57	28	17.95
polyploid annuals	21	23.08	35	22.44
polyploid perennials	22	24.18	34	21.79
	91		156	

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Observations Upon a Strain of *Streptomyces albus* Antagonistic to Certain Phytopathogenic Fungi

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Investigations of the antibiotic activities of the actinomycetes has for the most part been focused upon those organisms which are antagonistic to bacteria and fungi pathogenic to man. The inhibition of phytopathogenic fungi is at present of little more than academic interest since the chemotherapeutic treatment of plant disease is still in rather early stages of practical development, and the inoculation of soil with specific antagonists of soil inhabiting pathogens has not as yet met with conspicuous success. The more significant work in the latter field prior to 1945 has been reviewed by Waksman (8). Records of actinomycete antagonists of phytopathogenic fungi occur scattered through the literature, but very little appears to have been done in the way of extensive investigation. Alexopoulos (1) used a considerable number of actinomycetes in studies of the inhibition of *Colletotrichum gloesporioides*, and later with Herrick (3) tested a more limited group of actinomycetes upon various species of fungi. Meredith (5) reported actinomycetes to be antagonistic to *Fusarium oxysporium v. cubense*, causing the Panama disease of bananas, and Tims (7) has noted antagonism of a parasitic *Pythium* by an actinomycete.

The *Streptomyces* which is reported herein was discovered growing in a petri plate culture of the coffee leaf spot fungus, *Omphalia flavida*, and was presumably an air borne contaminant. It attracted attention because of the clear circular zone of inhibition several centimeters in diameter in the basidiomycete colony, with the colony of the antagonist only a few millimeters wide in the center of the zone. The *Streptomyces* was isolated in pure culture, and stock cultures were made in tubes of sterile soil according to the method of Green and Fred (4).

A selection was made of 28 species of fungi which were chosen to include several species from each class of the Eumycetes with particular attention to soil dwelling phytopathogenic species. One method of testing the antagonistic properties of the *Streptomyces* was that employed by Alexopoulos *et al* (2) in which the actinomycete is inoculated at two points 4 cm. apart on a plate of synthetic agar with maltose as the carbohydrate source. The fungus against which the actinomycete is to be tested is inoculated midway between the two actinomycete colonies after they have been incubated for five days. The inhibitory distance is determined as the average minimum distance between the fungus and actinomycete colonies at the time of first evidence of definite inhibition. Alexopoulos considered "strong inhibitors" to be those which showed an inhibitory distance of 10 mm. or more. Four plates were inoculated with each fungus tested. This number seemed adequate for a preliminary run since there was little variation within each group, and the purpose of the experiment was primarily exploratory. The observations of principal interest may be summarized as follows:

1. Varying degrees of complete or partial inhibition were demonstrated against 27 of the 28 test fungi. The single exception was *Gliocladium fimbriatum.* Partial inhibition is to be interpreted as marked reduction of normal growth of the fungus in the vicinity of the antagonist without complete prevention of growth. In the case of complete inhibition there is no growth whatever within the area of inhibition.

2. Both resistant and sensitive species were found in each class of fungi, supporting the observation of Alexopoulos and Herrick (8) that there is no general correlation between amount of inhibition and systematic position.

3. None of the fungi tested produced appreciable retardation of growth of the actinomycete.

4. Two phycomycetes *(Pythium debaryanum* and *Phytopthora cactorum)* and two basidiomycetes *(Pleurotus ostreatus* and *Omphalia flavida)* were unable to make any growth under the conditions of this test. These were apparently more marked inhibitions than those observed by Alexopoulos and his associates. When the *Streptomyces* was inoculated 8 cm. apart instead of the usual 4 cm., *Pythium* showed an average inhibitory distance of 3.4 cm.

The inhibitory effect of the *Streptomyces* was next tested against five species of fungi by a slightly modified version of the agar dilution method used by Reilly, Schatz and Waksman (6). The *Streptomyces* was grown on glucose-tryptone medium for eighteen days at room temperature. The culture liquid was then strained through cheesecloth and passed through a Seitz filter. The filtrate was added to melted potato dextrose agar and plates were poured in a series in which the filtrate was diluted from 1:5 to 1:200. The test fungi were then inoculated on the petri plates, and the diameter of the colonies was measured after 64 hours incubation at room temperature. Six plates were inoculated with each fungus at each dilution in addition to a set of controls to which no filtrate was added. It was found that *Helminthosporium sativum* was able to grow at all concentrations employed, although growth was markedly slower than the controls from 1:5 to 1:75. *Rhizopus nigricans, Aspergillus niger* and *Trichoderma viride* failed to grow at 1:5 and 1:10 dilutions and showed retarded growth up to 1:50 in the case of the *Aspergillus,* up to 1:100 in the case of *Trichoderma* and at all dilutions in the case of *Rhizopus. Pythium debaryanum* failed to grow in all cases. A second series was then set up with dilutions up to 1-1000 using only the *Pythium* as the test organism. Growth failed to occur at dilutions through 1-300 and was markedly retarded even at 1-1000, the *Pythium* colonies averaging 35 mm. in diameter after 48 hours incubation at room temperature in contrast to the 84 mm. diameter of the controls. It should be pointed out that the fungus inoculum in each case was taken from the periphery of a young colony of the fungus, so that continued mycelial growth rather than spore germination was being tested. These results are presented in greater detail in Table I.

TABLE I. Assay of *Streptomyces* Filtrate by Agar Dilution Method

Average diameter of test fungus colonies in millimeters after 64 hours incubation

Dilution of Streptomyces filtrate	Aspergillus niger	Trichoderma viride	Rhizopus nigricans	Helminthosporium sativum	Pythium debaryanum
1:5	0	0	0	4	0
1.10	0	0	0	6	0
1.20	6	9	5	15	0
1:30	9	17	8	17	0
1:50	12	25	15	22	0
1:75	11	32	20	22	0
1:100	12	35	40	25	0
1:150	14	43	45	26	0
1:200	..	.			0
1:300		.			0
1:500	..	.		.	36*
1:1000					52*
Control	13	40	90	32	90

* Incubated for 72 hours.

The antagonistic effect of the *Streptomyces* against *P. debaryanum* was further demonstrated in a somewhat different manner by inoculating the *Pythium* in the center of petri plates containing maltose-mineral salts agar. The plates were incubated for 40 hours, at which time the colonies were about 75 mm. in diameter. The *Streptomyces* was then inoculated at the edge of the rapidly growing fungus colony. Within the following 24 hours the *Pythium* covered the entire surface of the agar, but after a few days an expanding zone could be detected with its center at the site of the *Streptomyces* inoculum. This zone was characterized by a collapsed, watersoaked appearance of the fungus mycelium. Transfers of mycelium from these zones failed to grow when placed on sterile agar slants, indicating that under these experimental conditions the *Streptomyces* was able to cause the death of established *Pythium* mycelium in its vicinity.

The *Streptomyces* has been tested in a preliminary fashion against a number of bacteria commonly used in antibiotic assays, and against certain fungi pathogenic to man. Although a degree of inhibition was manifest in several instances, there was nothing sufficiently noteworthy to warrant further tests until such a time as it may be possible to concentrate or purify the active principle.

A culture of the *Streptomyces* was sent to Dr. S. A. Waksman who stated that it was similar to *Streptomyces albus* (Rossi Doria *emend.* Krainsky) Waksman and Henrici and that for the present it could be referred to as *S. albus* var. ST6. The varietal designation refers to the writer's culture number.

Morphologically the culture agrees fairly well with the description in the current 7th edition of Bergey's Manual. However it differs in several of its physiological reactions from those described for the species. Milk is not coagulated, a soluble brown pigment is produced in the liquefaction of gelatine, and starch is hydrolyzed. Gelatine liquefaction takes place very slowly. Certain of these properties, however, agree with earlier descriptions of *S. albus.* Abundant drops of exudate varying from nearly colorless to golden yellow were produced upon all media used which supported moderate to strong growth of the organism. The reaction upon litmus milk was quite distinctive. The milk was peptonized without coagulation, and the litmus was reduced. Then after a month or more of incubation the medium becomes blood red in color by transmitted light and increases in alkalinity to about pH 7.8.

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An Analysis of Floret Fertility in *Agropyron repens*

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In the summer of 1938 quackgrass, *Agropyron repens* (L.) *Beauv.*, spikes were collected for laboratory studies on noxious weeds. When ready for use in the fall it was observed that only a few of the florets were fertile. Since the amount of grain actually produced by quackgrass is a factor in its spread and control, an analysis of floret fertility was made.

Taxonomically, quackgrass belongs to the Hordeae tribe of the Gramineae. Phylogenetically the genus *Agropyron* is rather closely related to wheat and certain species of *Agropyron* have been known to hybridize with *Triticum.* Its vegetative and flowering periods are essentially the same as wheat.

As reported in the literature, quackgrass varies rather widely in its seed setting pattern. Such variation has been attributed largely to environmental factors but may also be due to genetic variability. In general, it appears that more seed has been produced on soils of average fertility than on the more fertile soils, and in drier seasons than in those of high rainfall.

Quackgrass is a perennial cool season plant which makes its best growth in cool moist climates and on soil of average to high fertility. It survives the rigors of winter better than the long, hot, dry summers.

Review of Literature

According to Quackenbush and Carter (9), quackgrass is a primary noxious weed in Indiana and one of the most serious weeds of that group. Deam (3) reports this grass chiefly in the northern two-thirds of the state yet it probably could be found in every county. While quackgrass was introduced from Europe, Eliot is credited by Kephart (5) with the first authentic report of the weed in this country in 1751. By 1850 it was well distributed east of the Allegheny mountains. It followed the emigrants westward and by 1890 had reached Minnesota. Quackgrass is now known to occur in all states north of the 35th parallel (Hitchcock, 4).

The geographic distribution of this weed has been further reported by Kephart (5) who states that it has been found as far north as the limits of cultivation, that it never winterkills and seldom becomes troublesome as a weed south of the Ohio River. He further states that quackgrass is a relatively poor seeder. Loose cultivated soil promotes good vegetative growth but fewer seeds. Oswald and Boss (7) state that each spikelet when mature contains from three to seven seeds. Arny (2) states that the spikes bear many seeds while Kephart (5) reports an average of twenty-five viable seeds per spike. Kephart further states that yields of quackgrass seed of eighteen bushels per acre have been obtained in Michigan.

Materials and Methods

Some eight hundred spikes of quackgrass were collected in the summer of 1938. In the fall, as previously stated, they were analyzed for floret fertility. In sampling this population for analysis each tenth spike was selected.

From eighty such spikes the following major determinations are made: average number of spikelets per spike; average number of florets per spikelet; percent of fertile florets; number of fertile florets per spike and the number of fertile florets per spiklet.

To determine seasonal variation, if any, these investigations were continued through 1939 and 1940. Larger collections were made the second and third years but the same sampling methods were used except that each twentieth spike was selected for analysis. Since approximately two thousand spikes were selected both the second and third year the total number analyzed each year was about the same.

These selections were made along fence rows and waste ground at the extreme south edge of the Purdue University Campus and adjacent to a large gravel pit. This soil is droughty but has produced fairly good crops of wheat and alfalfa. This land is classified as a Warsaw silt loam.

The temperature and rainfall records were from the Purdue University weather station about 60 rods from the quackgrass plots.

Experimental Results

Table I records the results obtained for the three year period.

TABLE I. Quackgrass Fertility Analysis

	1938	Year 1939	1940	Average
Number of heads selected for analysis	80	93	95	89.3
Total number of spikelets	1531	1581	1727	1613
Ave. Number spikelets per spike	19.14	17.0	18.71	18.28
Total number of florets	6736	7715	7783	7513
Ave. number of florets per spikelet	4.4	4.88	4.38	4.62
Ave. number fertile florets per spikelet	.49	.13	.78	.48
Ave. number fertile florets per spike	9.39	2.21	14.59	8.79
Percent of total florets fertile	11.2	2.7	17.4	10.27

Floret fertility, on a percentage basis, was found to be 11.2, 2.7 and 17.4 for each of the years, 1938, 1939, and 1940, respectively. The average number of grains ranged from 2.21 to 14.59 per spike and from 0.13 to 0.78 per spikelet. Even in the most favorable year less than one grain per spikelet was produced.

The floret analysis herein reported includes the total number of florets within the spikelet. It is generally known that, in the many-flowered spikelets in the grasses the percentage of floret fertility decreases from the lower to the upper nodes of the rachilla. Quackgrass appears to be in general agreement with this fertility pattern.

Weather records were obtained to correlate if possible temperature and precipitation with fertility.

Climatological data (1) giving precipitation and temperature recorded as departure from normal are presented in Table II.

TABLE II. Precipitation and Temperature Data Obtained from Climatological Reports.

Months reported	Figures recorded as departures from normal					
	1938		1939		1940	
	Precp.	Temp.	Precp.	Temp.	Precp.	Temp.
May	+1.67 in.	+0.6°F.	—3.35 in.	+5.1°F.	0.0 in.	—1.6°F.
June	+0.03 in.	—0.1°F.	+1.36 in.	+3.9°F.	+0.39 in.	+2.1°F.

These figures indicate that the year of highest June rainfall was accompanied by the lowest floret fertility, while in years when June rainfall was more normal floret fertility was higher. The figures further show that 1939 was the year of highest June temperature and was associated with the lowest floret fertility. Due to the flowering period of quackgrass it appears that May rainfall would have less influence on floret fertility than would rainfall in June. In Central Indiana quackgrass flowers the first half of June, sometimes starting in late May. Generally, however, the flowering period is over and the grains quite well matured by early July.

Discussion of Results

In general weeds produce seed in very large numbers. One investigator (6) found that some weeds produce several hundred thousand seeds per plant while in a few cases the estimate (Peterson and Tingy, 8) has been up to a million seeds per plant. In general the weedy species in the grass family produce less seed than do many weedy plants in other families.

All weeds branded as primary noxious by law in Indiana (Quackenbush and Carter, 9) propagate vegetatively as well as by seed. In general, where vegetative reproduction is well developed the plant has reduced its tendency to reproduce by seed. This reduction in seed may be caused by a reduced number of flowers or by flower sterility. There is ample evidence of floret sterility in many of the grasses. It is well known that vegetatively Canada thistle, *Cirsium arvense* (L.) Scop., and field bindweed, *Convolvulus arvensis* L. spread rapidly by vegetative reproduction yet neither of these two species produces many seeds in this area. On the contrary, Johnson grass, *Sorghum halepense* (L.) Pers. is very aggressive vegetatively yet with little apparent reduction in its ability to produce seed.

While rhizomes and creeping roots are effective in the dissemination of weedy species they are most effective when carried short distances. Seeds, however, often retain their viability for many years, and may be carried great distances by means of agricultural seed or other agencies.

While quackgrass under the conditions of the experiment produced few seeds in this area one would not be entirely justified in assuming that such seed is a negligible factor in the spread of this weed. According to the data presented quackgrass produces some seed every year and an appreciable amount of seed in the more favorable years. Such seed is no doubt a very definite factor in the dissemination of the species, being carried through forage crops, crop residues, manure, and agricultural seed. Such seed provides a constant source of infestation of new areas.

These results indicate that high temperature or heavy precipitation or both may reduce floret fertility in quackgrass. Although definite conclusions should not be drawn from three years data these results are in general agreement with greater floret fertility found in the western and northern states where lower temperatures and rainfall prevails. The separate effects of these two factors are not known.

Summary and Conclusions

Floret fertility of quackgrass, *Agropyron repens*, as determined by the number of seeds found at maturity was relatively low in central Indiana. There was considerable annual variation.

Higher than normal June rainfall and higher than normal June temperature were associated with reduced floret fertility.

Quackgrass sets some seed every year and an appreciable amount during the more favorable years.

When the usual methods of seed dissemination are considered even low yields of quackgrass seed must be an important source of infestation for new areas.

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The Algae of the Edmund Niles Huyck Preserve

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The Edmund Niles Huyck Preserve is a private wild-life sanctuary near Rensselaerville, N. Y. It was established in 1931 as a memorial to Edmund Niles Huyck and is managed by a corporation, which made possible this brief study in the summer of 1946.

The Preserve consists of Lincoln Pond, of about four acres, and Myosotis Lake, of about eighty acres, and Tenmile Creek, which drains them and which includes a series of cascades called Rensselaerville Falls; also the most of the watershed of this drainage-system.

The two artificial bodies of water, Lincoln Pond and Lake Myosotis, have assumed the habitat-characteristics of natural lakes, except that the practically constant level, maintained by dams, prevents the catastrophic seasonal changes of natural lakes, levels of which may vary greatly. Such uniform habitats often show large populations of algae, but a relatively small number of species, which may remain for long periods in the vegetative condition, making identification difficult beyond the genus. A floating species of *Oedogonium* was the most conspicuous alga of the lakes, collecting in masses above the dams and on the spillways. At times blue-green algae, in the form of water-blooms, become so abundant that copper sulfate is used to destroy them; but they were not abundant at the time of this study.

Tenmile Creek passes by a series of cascades thru a postglacial gorge cut thru the Hamilton flags and shales and the Oneonta red beds of the Middle Devonian. On the faces of the cascades grew scattered colonies of *Lemanea (Sacheria)*, intermingled with various attached green algae, especially *Cladophora.*

The walls of the gorge are in many places permanently moist from seepage. Here occur gelatinous masses composed of mixtures in various proportions of *Nostoc microscopicum* Born. & Flah., *Anacystis rupestris* (Lyngb) Dr. & Daily, *Aphanothece, Chroococcus turgidus* (Kütz) Näg., *Cylindrospermum majus* Born. & Flah. and *Gloeothece rupestris* (Lyngb.) Born. *Scytonema figuratum* Born. & Flah. *Anacystis rupestris* and *Glococapsa alpicola* (Lyngb) Born formed lichen-like colonies on shaded walls, associated with the "fleece lichen".

In swift water at the falls occurred *Plectonema Thomasinianum* Gom., forming tenacious, dark-green closely-adherent incrustations on rocks. *Nostoc sphericum* Born. & Flah. formed tough spherical colonies where spattering from the cascades occurred.

Because of the frequent showers characteristic of the region, soil algae were common. *Nostoc muscorum* Born. & Flah., *Microcoleus* *vaginatus* Gom and *Cylindrospermum muscicola* Born. & Flah. formed dark green patches on moist soil.

One of the most notable collections was made in a shallow bay of Basic Reservoir, where *Pediastrum* occurred in very great abundance. *Pediastrum Boryanum* (Turp.) Menegh. and *P. duplex* Meyen were the principal species and were accompanied by small quantities of *Scenedesmus quadricauda* (Turp.) Breb. *Pediastrum* is commonly found as isolated colonies among filamentous algae or as plankton; but such an occurrence as this is apparently rather unusual.

The principal lake-bottom inhabitants were the Characeae. *Chara coronata* Ziz. was common in Lake Myosotis and in a beaver-pond north of Rensselaerville. *Nitella flexilis* also occurred in Lake Myosotis.

The Rhodophyceae were well represented, as follows: *Sacheria (Lemanea) fucina* (Bary) Sirod at Rensselaerville Falls, growing with green algae on edges of cascades; *Adouinella violacea*, forming a continuous, extensive, bright-violet area where the trickle of water fell from a height of about thirty feet on a flat ledge at Felter's Glen, a deep, narrow, shaded rock gorge; *Batrachospermum moniliforme* Roth in a small, cold, spring-fed brook; the apparent *Chantransia*-form of *Batrachospermum* at The Vly, a peat bog.

Further study at other seasons of the year will be necessary in order to complete the catalog of algal species occurring in the Preserve and its environs.

Grateful acknowledgments of the writer at due to Dr. Francis Drouet, of the Chicago Museum of Natural History, for identifying the blue-green and green algae; to Dr. Mervin Palmer and Mrs. William A. Daily of Butler University, for work with the Rhodophyceae and the Characeae.

Beech in the Forests about Laughery Creek Valley[1]

J. E. POTZGER, Butler University

LELAND CHANDLER, Purdue University

Laughery Creek today meanders through a wide, magnificent valley, deeply entrenched in Ordovician rock strata. The majestic power of great masses of water which Laughery Creek carried in early post-glacial times is still evidenced in the silent grandeur of the high slopes and carved rocks. The master stream imposed his cutting power upon the smaller tributary creeks, so that the region presents a wide range of habitats with their selective action on plant life. This in turn results in segregation of species of trees and of forest types.

The region in general lies within the old Illinoian tillplain. These tillplain habitats are severaly leached. Not only is the topography flat but the land offers great problems to the agriculturist. The greyish-brown soil is compacted to a degree that one wonders how roots of trees can ever penetrate, or how proper aeration can be attained. On the other hand, the nearby steep, rocky slopes may lack sufficient soil moisture during much of the growing season. Between the two extremes appear numerous habitats which are intermediate. This means variation in forest cover types in the various habitat sites.

We became interested in the wide range of *Fagus grandifolia* (beech) in this part of Ripley County. It is present in forests on the poorly-drained tillplains as well as in those on well-drained gentle north and east-facing slopes. While beech is present consistently in the whole range of different habitat sites, the associates vary much. This unique characteristic of *Fagus* suggested the present study in the Laughery Creek valley (Fig. 1). The numbers on the map used to show location of the various forests are the same as those designating tables ond forest descriptions.

Location and Descriptions of the Forests

1. Versailles State Park stand is located within the park area, beginning at the fire tower road and running eastward. It covers about 10 acres. While there is little evidence of modifying cultural influence, some selective cutting may have taken place.

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[1] This is contribution 216 of the botanical laboratories of Butler University and contribution 3 of the faculty of the Purdue-Department of Conservation Education Camp.

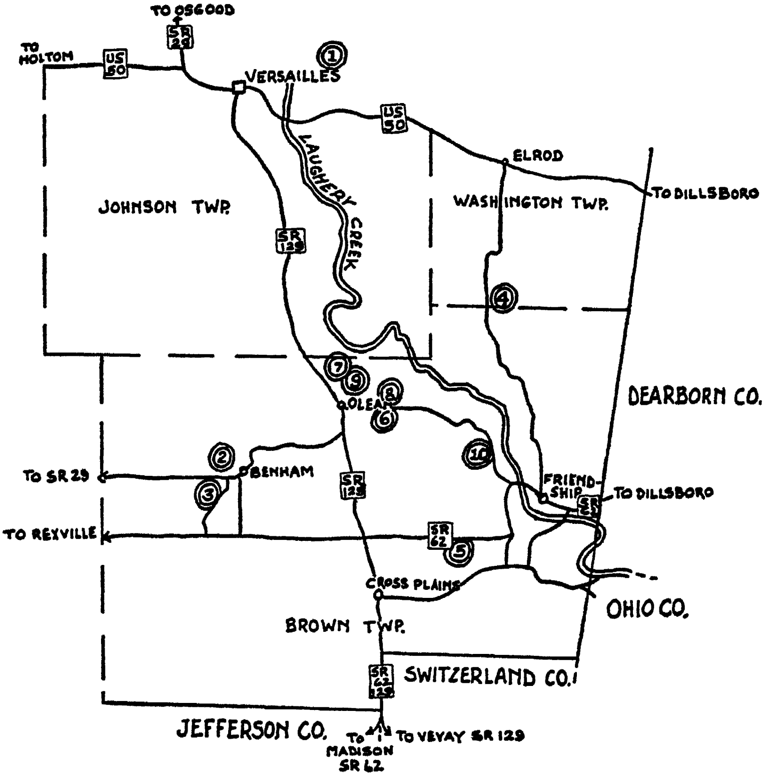


Figure 1. Partial map of the Laughery Creek valley to show location of forests studied.

2. J. H. Schwagmeier woods. It is one mile west of Benham. The area is between 20 and 25 acres. A small, shallow creek drains the wooded area. No cultural disturbance is evident.

3. W. S. Lemon woods. Its location is two miles southwest of Benham and 3.5 miles northwest of junction between roads 62 and 129. The area is about 15 acres. About half of the forested land is typical Illinoian tillplain habitat. The other half is influenced by drainage. Some intermittent streams penetrate the area and a deep ravine flanks the outer part. Pasturing and some cutting have been and are modifying influences.

4. Fred Cutter woods. This woods is located three miles north of Friendship, and three miles south of Elrod, on the Elrod-Friendship pike, along the Washington-Browntownship line. The area comprises about 10 acres. Only a few sections have suffered cutting.

5. Henry Thielking woods. Its location is 2.5 miles west of Friendship on state road 62; two miles east of junction between highways 62 and 129. Area is about 25 acres. This is a magnificent stand of timber,

in its prime. A few large *Juglans nigra* (walnut) were taken out about 10 years ago. No other cultural influences have played a part in the development of the stand. A small intermittent stream drains the center. The habitat is, thus, of the drained Illinoian tillplain type.

6. Ervin Thielking woods. The stand is located one mile east of Olean, on the Friendship-Olean pike, south side of the road. The forest covers about 20 to 25 acres. While the periphery of the forest shows evidences of some cutting, no disturbance of natural conditions is evident in the section where the tabulations were made. Both shallow and deep ravines give evidence that drainage is adequate.

7. Wm. J. H. Otte woods. Its location is one mile north of Olean on state road 129, and a half mile south. There is disturbance by some pasturing and cutting. Most of the stand is located on a steep slope to a Laughery valley tributary stream. Exposure is north-east.

8. George Stegemoller woods. This stand is one mile east of Olean on the Friendship-Olean pike, north side of the road. It covers approximately 15 acres. No modifying cultural influences were evident.

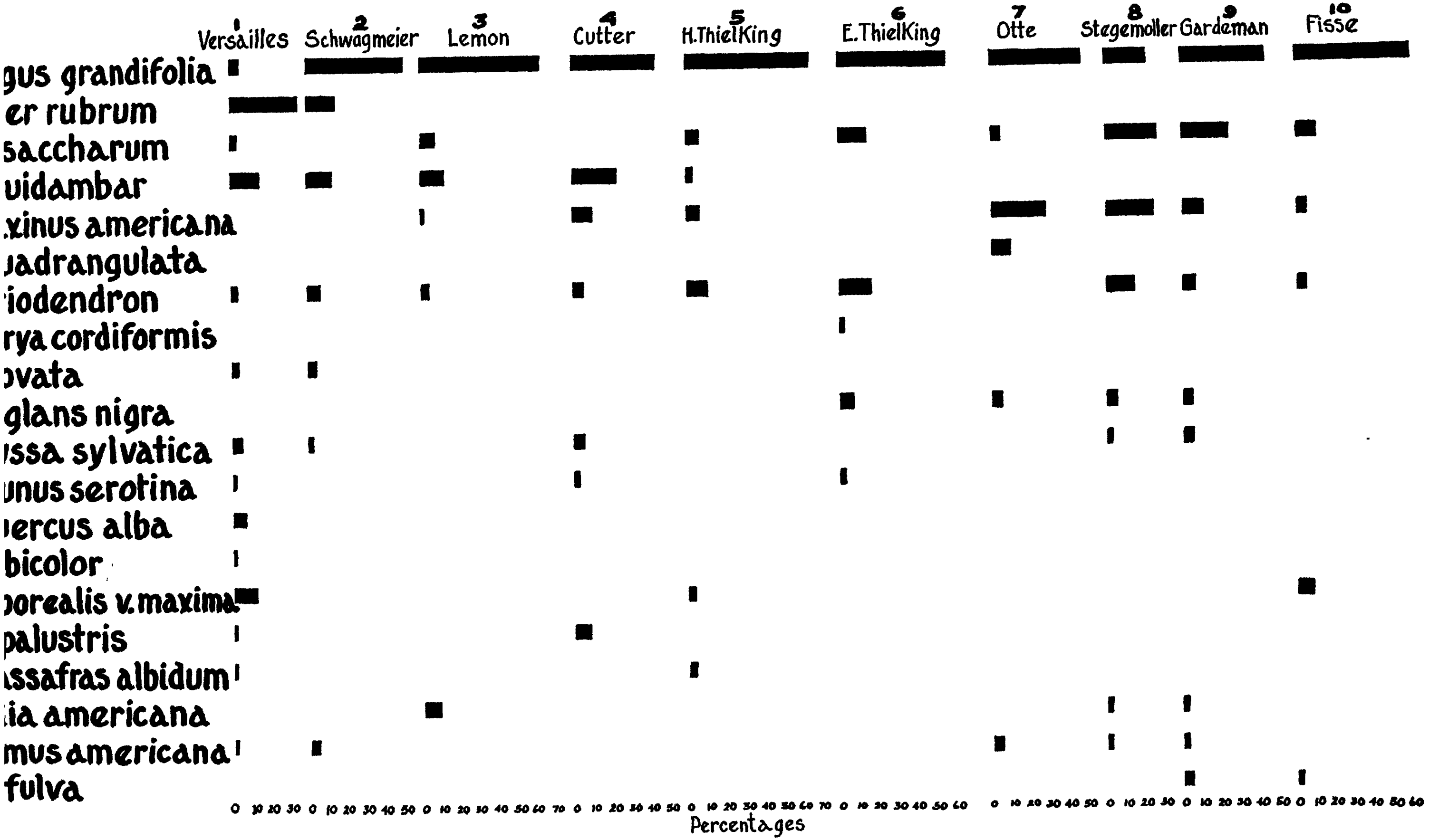
9. Wm. Gardeman heirs woods. Location of the 60 acres is one mile north of Olean on state road 129, and a half mile south. The topography is a rather narrow plateau of Illinoian tillplain type soil bordered by steep slopes to Laughery valley on the one side and to Raccoon Creek on the other. It is a mature stand of timber which has had a limited amount of selective cutting as modifying influence.

10. Frank Fisse woods. It is located one mile west of Friendship on the Friendship-Olean pike, north of the road. It covers about 5 acres. The topography is a long gentle west-facing slope with several secondary north-facing slopes faceting. The whole area is drained by a small creek. There is some evidence of former pasturing.

Methods

The junior author lived in Friendship, Indiana and was personally acquainted with the owners of the various stands, and he made all arrangements with the owners to have the studies carried out on the various properties.

With the exception of the Otte woods, woody species in twenty 10-meter-square quadrats were tabulated to obtain data on the sociology in the forests. In the Otte woods only ten such quadrats were studied. Each quadrat was delimited with a stout cord with loops at ten-meter intervals. The loops were slipped over wooden stakes driven into the ground. Stems 1-inch or over DBH. were measured with wooden calipers. Stems of smaller diameter were counted if height was at least 3 feet. Tables I to X present for each stand the stems in several diameter size-classes, the abundance and the per cent F. I. All stems 9 inches DBH. or over are considered of sufficient height to be represented in the crown cover. The percentage of the total of such stems which a given species had in the stand is shown graphically in figure 2. The aim was to find all types of habitats where beech formed a part in the forest



e 2. Percentage of stems 9 inches or over DBH. which any given species has of the total of such stems in a given forest. A method to show importance in crown cover.

complex. The habitats were representative of poorly-drained Illinoian tillplain (Tables I, II, III, VIII), partly dissected Illinoian tillplain (Tables IV, V, VI, IX), and east and north-facing slopes (Tables VII, X).

Results

While Tables I to X and figure 2 present the sociology in the various stands, a few important points will be re-stated. Most of the species of trees had low fidelity, only *Fagus grandifolia Acer saccharum* and *Fraxinus americana* showed 100 per cent fidelity, i.e., they appeared in every one of the ten stands. *Liriodendron tulipifera* (tulip poplar) and *Fraxinus quadrangulata* (blue ash) had a fidelity of 90 per cent. *Prunus serotina* (black cherry) *Ulmus americana* (American elm) recorded 80 per cent. If we consider importance in crown control (Fig. 2) only beech is consistently represented at all stations in the large-stem sizes. *Acer saccharum* (sugar maple) has a high fidelity, exhibits tre-

TABLE I. Tabulation of woody species in twenty 10-meter-square quadrats in Versailles State Park. Diameter classes in inches. (DBH.)

Species	Below 1 in.	1-2	3-5	6-8	9-15	16-20	Above 20	Total stems	Per cent F.I.
Acer rubrum	8	24	24	16	16	4	1	93	75
A. saccharum	4	3	2		1		1	11	35
Amelanchier canadensis		1	1					2	5
Carpinus caroliniana	29	25	12	1				67	60
Carya laciniosa	6	3	1					10	15
C. ovata	27	18	8	2	2			59	80
Cornus florida	11	4						15	30
Fagus grandifolia	28	44	18	2			3	95	80
Fraxinus americana	19	13	5	4				41	70
Liquidambar styraciflua	1	3	9	5	5	4		27	65
Liriodendron tulipifera		1	1	1	1	1		5	20
Morus rubra	2							2	5
Nyssa sylvatica	1	1	3	2	3			10	25
Ostrya virginiana	16	2	2					20	20
Platanus occidentalis					1			1	5
Prunus serotina	1				1			2	10
Quercus alba	11	5	7	3	3		1	30	70
Q. bicolor				1	1			2	5
Q. borealis var. maxima	4	5	4	2	6	1		22	65
Q. palustris						1		1	5
Sassafras albidum	1		8	11	1			21	55
Ulmus americana	2	7	6	2	1			18	40
U. thomasi		2						2	5
Corylus americana	7							7	10
Lindera benzoin	78							78	20
Smilax glauca	89							89	50
Viburnum dentatum var. deamii	38							38	35
Vitis sp.?	1							1	5

TABLE II. Tabulation of woody species in twenty 10-meter-square quadrats in the Schwagmeier woods. Diameter classes in inches. (DBH.)

Species	Below 1 in.	1-2	3-5	6-8	9-15	16-20	Above 20	Total stems	Per cent F.I.
Acer rubrum	6	3	3	1	3	2	2	20	40
A. saccharum	4	1	1					6	20
Carpinus caroliniana			1					1	5
Carya glabra	1							1	5
C. ovata	87	13		2	1		1	104	90
Fagus grandifolia	249	11	5	1	8	12	4	290	90
Fraxinus americana	4		1	1				6	25
Liquidambar styraciflua	40	5	1	3	5		1	55	65
Liriodendron tulipifera	20	4		1	3			28	30
Morus rubra	4							4	20
Nyssa sylvatica			1		1			2	10
Prunus serotina	1							1	5
Sassafras albidum	1							1	5
Ulmus americana	2	2	1		2			7	30
U. fulva	1							1	5
Aralia spinosa	12	8	1					21	20
Lindera benzoin	209							209	65
Rosa sp.?	10							10	5
Rubus allegheniensis	6							6	15
Sambucus canadensis	17							17	30
Smilax glauca	55							55	75
Viburnum acerifolium	3							3	5

mendous reproduction in most mesic habitats, but seldom attains great abundance in the large size-classes. All shrubs, except *Smilax glauca* (green briar) and *Vitis* sp.? (grape) have a fidelity of 70 per cent or less. While 18 species of shrubs and 6 of small trees are present in the ten stands, none have sufficient abundance to produce well-defined strata.

Trees of Large Diameter

The farther we become removed from pioneer days and forest primeval the more we may feel inclined to believe that a large percentage of the trees constituting the forest primeval were of gigantic size, and so it is perhaps justified to add a few records gleaned from the study of ten stands in the Laughery Creek valley, which as a whole had not been disturbed greatly. Potzger and Friesner (3,4) pointed out that trees with extremely large diameters very likely were not so common as stories by "old timers" and idealized descriptions by early travelers might make one believe. Any description of a forest which is not based on some quantitative sampling is very likely to be far from accurate. In the ten stands we recorded 17 stems 30 inches or over DBH. Figures in parentheses refer to the forest or forests where these trees were observed. *Acer saccharum,* 36, 36 (5); *Carya cordiformis,* 39 (6); *Fagus grandifolia* 30 (10); 30, 30 (9); 30 (4); 30, 33, 36, 37 (6); 30, 37, 38 (5); *Nyssa sylvatica,* 34 (4); *Quercus borealis* var. *maxima,* 35 (5).

Discussion

The senior author last year studied the range of forest cover types in the Versailles Park area (2) and found that the climate-favored climax forest occupies the most mesophytic habitats, and with changes in soil moisture conditions the two most important dominants in it, *Fagus grandifolia* and *Acer saccharum* separate as associates and we find them as co-dominants in different association complexes. Beech extends its range to the moist or wet Illinoian tillplain habitat and sugar maple to the drier sites on slopes which are usually characterized by oaks and hickories.

Since the present study had as specific aim the examination of beech and its association ranges, the habitats selected were of necessity those where soil moisture was favorable to abundant. If the sociological factors abundance and F. I. are considered (Tables I to X) one finds less segregation into forest cover types than is accentuated if crown cover alone is considered (Fig. 2). However, the latter factor is the most important one in the forest of the present. While reproduction is significant, one should not use it too extensively for predictions with

TABLE III. Tabulation of woody species in twenty 10-meter-square quadrats in the Lemon woods. Diameter classes in inches. (DBH.)

Species	Below 1 in.	1-2	3-5	6-8	9-15	16-20	Above 20	Total stems	Per cent F.I.
Acer negundo	1							1	5
A. rubrum		4	1					5	10
A. saccharum	14	6	3	2	4			29	35
Carpinus caroliniana	2	1	1					4	5
Carya cordiformis	2							2	10
C. ovata	8	8	1	1				18	25
Cornus florida	8	3		5				16	50
Fagus grandifolia	71	8	2	1	9	13	8	112	100
Fraxinus americana	5						1	6	15
F. nigra	1							1	5
Juniperus virginiana	5							5	10
Liquidambar styraciflua	9	9	3	4	2			27	30
Liriodendron tulipifera		1			1		1	3	15
Ostrya virginiana	11	1						12	35
Prunus serotina	1							1	5
Quercus alba	3							3	10
Q. palustris	1							1	5
Tilia americana	1				?	1		5	15
Ulmus americana	1	1						2	10
Aralia spinosa	8	1	3					12	15
Asimina triloba	2							2	5
Lindera benzoin	97	1						98	30
Rubus allegheniensis	7							7	25
Smilax glauca	396							396	25
Vitis sp.?	5							5	10

TABLE IV. Tabulation of woody species in twenty 10-meter-square quadrats in the Cutter woods. Diameter classes in inches. (DBH.)

Species	Below 1 in.	1-2	3-5	6-8	9-15	16-20	Above 20	Total stems	Per cent F.I.
Acer rubrum	7	1	2					10	15
A. saccharum	12			1				13	30
Aesculus glabra			1					1	5
Carya glabra	3	1	1					5	20
C. ovata	3		1					4	15
Cornus florida	80	16	9					105	70
Fagus grandifolia	64	53	42	17	3	4	10	193	95
Fraxinus americana	19	11	6	4	3	1		44	45
Liquidambar styraciflua	4	2	3	1	9			19	30
Liriodendron tulipifera				1	1	1		3	15
Morus rubra			1					1	5
Nyssa sylvatica	2		1				2	5	15
Ostrya virginiana	15	9	6					30	45
Prunus serotina	1			1	1			3	15
Quercus borealis var. maxima		1						1	5
Q. palustris					3			3	10
Ulmus americana	1	1		2				4	20
U. thomasi		1	1					2	5
Aralia spinosa		1						1	5
Rhus radicans	41							41	15
Ribes sp.?	2							2	5
Sambucus canadensis	1							1	5
Smilax glauca	7							7	15
Viburnum acerifolium	4							4	10
Vitis sp.?	6	13	1					20	30

reference to composition of forests of the future. This has been stressed repeatedly by the senior author with reference to sugar maple and ash. One can gain some concept of the variation in association complex within the ten stands by a brief survey of the ten tables. We find 31 species of tall trees and 6 species of small trees participating in the sociology of the ten stands, but of these 31 the maximum representation in any one stand is 19 and the minimum is 11. This makes one wonder how much of the association aggregation is an expression of selection by habitat factors and how much is chance priority due to early invasion when the stand first developed. Potzger and Potzger (5) found different forest cover foreshadowed because of chance to invade an open area before larger numbers of one or more species occupy the crown cover. Since trees are long-lived, the crown cover once closed will very likely remain more or less static for centuries. One survey can hardly discover all such factors. This characteristic prompted Gleason (1) to sponsor the individualistic concept of the plant association, which is determined by space and time.

If one were to apply the classification of foresters, based on forest cover types, a remarkable heterogeneity would be noticed in the forests about Laughery Creek valley, viz. beech-sweet gum (3); beech-red maple-sweet gum (2); red maple-sweet gum-beech (1); beech-sweet gum-ash (4); beech-sugar maple (10); beech-sugar maple-ash-tulip poplar (8); beech-ash (7). This can mean only a great potentiality of beech to fit into a wide range of microclimatic factors in habitats which are in the moist to wet class.

The Laughery Creek valley environment is no doubt favorable to beech, this is shown by crown control (Fig. 2) in various habitat sites as well as by abundant to prolific reproduction (Tables I to X). It appears that beech reproduces best in habitats where moisture is abundant. It is usually not reproducing prolifically in the climax mixed mesophytic forest type. It is therefore a mystery why beech does not invade floodplain areas.

While beech is a constant participant in all ten stands studied, associates may indicate variation in habitat factors. Thus, *Liquidambar styraciflua* (sweet gum) and *Acer rubrum* (red maple) designate poor

TABLE V. Tabulation of woody species in twenty 10-meter-square quadrats in Henry Thielking woods. Diameter classes in inches. (DBH.)

Species	Below 1 in.	1-2	3-5	6-8	9-15	16-20	Above 20	Total stems	Per cent F.I.
Acer saccharum	191	65	44	12	2			314	100
A. rubrum	8			1				9	5
Carya cordiformis	1							1	5
Carya ovata	8	4	1					13	10
Cornus florida	67	13	14	1				95	90
Fagus grandifolia	57	11	2	1	2	5	12	90	100
Fraxinus americana	14	1			1	1		17	35
F. quadrangulata	1							1	5
Liriodendron tulipifera	29	1	1	1	2		1	25	70
Nyssa sylvatica	62	5					1	70	30
Ostrya virginiana	35	1	2					38	55
Prunus serotina	15	1						16	30
Quercus borealis var. maxima							1	1	5
Sassafras albidum	7		1		1			9	25
Ulmus americana	1	3						4	10
U. fulva	19	2						21	30
Aralia spinosa	8							8	20
Celastrus scandens	4							4	5
Evonymus atropurpureus	1							1	5
Rhus radicans	2							2	5
Rubus allegheniensis	7							7	10
Smilax glauca	19							19	15
S. hispida	33							33	30
Viburnum acerifolium	2							2	5
Vitis sp.	9	14						23	15

TABLE VI. Tabulation of woody species in twenty 10-meter-square quadrats in Ervin Thielking woods. Diameter classes in inches. (DBH.)

Species	Below 1 in.	1-2	3-5	6-8	9-15	16-20	Above 20	Total stems	Per cent F.I.
Acer saccharum	160	108	43	24	5		1	341	100
Carpinus caroliniana	1	2						3	5
Carya cordiformis							1	1	5
C. glabra	1							1	5
Cornus florida	10	10	8					28	55
Fagus grandifolia	18	10	1	1	2	5	17	54	95
Fraxinus americana	94	3		1				98	70
F. pennsylvanica	3	1						4	5
Juglans nigra	1		1		3			5	10
Liriodendron tulipifera	2				6	1		9	25
Morus rubra	10							10	25
Prunus serotina	14				1			15	20
Quercus borealis var. maxima	2	1						3	10
Asimina triloba	5							5	10
Lindera benzoin	4							4	15
Rubus occidentalis	1							1	5
Viburnum acerifolium	17							17	25
Vitis sp.?	1							1	5

TABLE VII. Tabulation of woody species in ten 10-meter-square quadrats in the Otte woods. Diameter classes in inches. (DBH.)

Species	Below 1 in.	1-2	3-5	6-8	9-15	16-20	Above 20	Total stems	Per cent F.I.
Acer saccharum	14	18	6		1			39	80
Aesculus glabra		2						2	10
Carpinus caroliniana				1				1	10
Carya cordiformis		2	1					3	20
Cornus florida			1					1	10
Fagus grandifolia	4	2	1			5	5	17	80
Fraxinus americana	2				3	1	2	8	50
F. quadrangulata					1	1		2	20
Gymnocladus dioica		1						1	10
Juglans nigra						1		1	10
Morus rubra	1							1	10
Ostrya virginiana	22	4						26	50
Tilia americana	1		1					2	20
Ulmus americana	2	9	15	1			1	28	90
U. fulva			1					1	10
Asimina triloba	31	2						33	70
Evonymus atropurpureus	12							12	20
Lindera benzoin	54	3						57	40
Ribes sp.?	24							24	50
Rubus allegheniensis	15							15	20

drainage on the Illinoian tillplain, sugar maple indicates the climax where optimum mesophytism prevails in the site. Less diagnostic are such species as tulip poplar, American ash and *Nyssa sylvatica* (sour gum). Their range is wide, and frequently similar to that of beech.

Summary and Conclusions

1. The paper presents data on ten forest stands in the Laughery Creek valley (Ripley County, Indiana) in which *Fagus grandifolia* is an important dominant.

2. The habitats where beech is important include poorly-drained Illinoian tillplain, well-drained Illinoian tillplain and well-drained north and east-facing slopes.

3. *Fagus* has a fidelity of 100 per cent but associates vary much. Figure 2 shows graphically the percentage of stems 9 inches or over DBH. which any species had of the total number of such stems in a given forest.

4. Beech reproduces very abundantly in wet habitats but not so well in the most mesophytic habitats.

TABLE VIII. Tabulation of woody species in twenty 10-meter-square quadrats in the Stegemoller forest. Diameter classes in inches. (DBH.)

Species	Below 1 in.	1-2	3-5	6-8	9-15	16-20	Above 20	Total stems	Per cent F.I.
Acer saccharum	272	61	49	32	11			423	100
Carya cordiformis	5			1				6	15
Celtis occidentalis					1			1	5
Cornus florida	1	5	1	1				8	20
Fagus grandifolia	10	10	2	1	1		8	32	65
Fraxinus americana	19			1	5	4	1	30	50
F. pennsylvanica	7							7	5
F. quadrangulata	1							1	5
Juglans nigra					2			2	10
Liriodendron tulipifera					4	2		6	20
Morus rubra	17	3						20	45
Nyssa sylvatica					1			1	5
Prunus serotina	11							11	30
Quercus alba			1					1	5
Tilia americana					1			1	5
Ulmus fulva	7	3	1					11	25
Aralia spinosa	1							1	5
Asimina triloba	97	5						102	35
Parthenocissus quinquefolia	5							5	5
Sambucus canadensis	1							1	5
Smilax glauca	5							5	10
Vitis sp.?	1	8	1					10	15

TABLE IX. Tabulation of woody species in twenty 10-meter-square quadrats in the Gardeman forest. Diameter classes in inches. (DBH.)

Species	Below 1 in.	1-2	3-5	6-8	9-15	16-20	Above 20	Total stems	Per cent F.I.
Acer saccharum	24	31	12	5	10	1		83	70
Aesculus glabra	1							1	5
Carpinus caroliniana	2	1						3	15
Carya cordiformis	1							1	5
Cornus florida	15	3						18	35
Fagus grandifolia	27	6	3		2	5	13	56	80
Fraxinus americana	9	1	1	2		5		18	45
F. quadrangulata		1						1	5
Juglans nigra					2			2	10
Juniperus virginiana	1							1	5
Liriodendron tulipifera	18				2	1		21	30
Nyssa sylvatica	38							38	45
Ostrya virginiana	17	1	1					19	35
Prunus serotina	2							2	5
Quercus muhlenbergii	2							2	5
Sassafras albidum	8							8	15
Tilia americana	14		1		1			16	10
Ulmus americana	5	3		2	1			11	35
U. fulva	9	1			1	1		12	30
Aralia spinosa	7	2						9	15
Asimina triloba	106	10						116	30
Lindera benzoin	380	7						387	95
Ribes sp.?	11							11	10
Rhus radicans	6							6	5
Rubus allegheniensis	188							188	50
R. occidentalis	2							2	5
Smilax glauca	57							57	40
Vitis sp.?	1	1						2	10

5. Forest cover types represented in the ten stands are as follows: beech-sweet gum; beech-sweet gum-red maple; red maple-sweet gum-beech-oak; beech-sweet gum-ash; beech-sugar maple-ash; beech-tulip poplar-sugar maple; beech-sugar maple; beech-sugar maple-ash-tulip poplar; beech-ash.

6. While 31 species of tall trees are recorded in the ten stands, only 11 to 19 of these were found in any one forest.

7. No well-defined small tree and shrub strata were found.

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TABLE X. Tabulation of woody species in twenty 10-meter-square quadrats in the Frank Fisse woods. Diameter classes in inches. (DBH.)

Species	Below 1 in.	1-2	3-5	6-8	9-15	16-20	Above 20	Total stems	Per cent F.I.
Acer saccharum	7		1		2	1	1	12	40
Carpinus caroliniana	20	4	6					30	20
Carya cordiformis	4							4	5
C. ovata		1	3					4	10
Cercis canadensis	3			2				5	10
Cornus florida	18	3	6	3				30	45
Fagus grandifolia	18	1				4	19	42	95
Fraxinus americana	3	1	5		2			11	20
Juniperus virginia	18	5						23	45
Liriodendron tulipifera					1		1	2	5
Nyssa sylvatica	7	2	1		1		1	12	30
Ostrya virginiana	143	12	15	1				171	70
Quercus alba			1					1	5
Q. borealis var. maxima						1	2	3	10
Ulmus americana			1	1	1			3	10
U. fulva	2					1		3	15
Asimina triloba	31	6						37	15
Evonymus atropurpureus	10							10	20
Lindera benzoin	3							3	5
Ribes sp.?	5							5	5
Rubus allegheniensis	26							26	15
Smilax glauca	16							16	20
Vitis sp.?	2	9						11	10

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Secondary Succession in an Illinoian Tillplain Habitat[1]

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The work presented here marks the beginning of an observation on the progress of secondary succession on an abandoned farm adjacent to a comparatively little disturbed mature stand of the sweet gum-red maple-beech type of forest. Observation was based on twenty 10-meter-square permanent quadrats. The land has not been under cultivation for about fifteen years, and forest is well established as a vigorous young *Liquidambar-Acer rubrum* associes.

Since appearance of Cowles (1) classical studies on succession in dunes habitats ecologists have been conscious of the dynamic aspect of vegetation. This characteristic is present both in primary and secondary succession. The literature does not lack papers on progress of secondary succession based on short-time observations or on inference, but it lacks reports on actual changes shown by long-period and repeated observations in the same area. Also, the authors do not know of a single paper which deals with secondary succession in the unique sweet gum-red maple-beech association. Hence, a study of the type forming the basis of this paper seems to be justified.

The area studied has an excellent location. It is bordered by a rather mature forest of the type to which succession is progressing, and being a part of Versailles State Park, cultural influences will play no part in the years to come. It would, of course, have been most desirable to have records from the very beginning of the succession tendencies, but it is fortunate at least that succession has not advanced far beyond the first wave of invaders, who apparently were able to establish themselves under least favorable soil moisture of the abandoned field. Likewise, at this stage the young trees have not produced seeds and so played no part in the seedling population.

Geography and Physiography

The area is within the limits of Versailles State Park, one mile east of Versailles, Ripley County, Indiana. The region as a whole lies within the severely leached Illinoian Tillplain. Habitat sites are varied because of the proximity to Laughery Creek and its tributaries. In spite of cutting action of the streams, there are still some extensive table lands with poor drainage, and these are characterized, as described previously by the senior author (3), by the sweet gum-red maple-beech type of forest association. The abandoned field under consideration is located a half mile east of the fire tower road, within the park proper. Topographically it is a flat, poorly-drained table land bordering on a better drained low upland.

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[1] This is contribution 215 of the botanical laboratory of Butler University and contribution 2 of the faculty of the Purdue-Department of Conservation Education Camp.

Methods

The association complex of the adjacent mature forest was studied on basis of twenty 10-meter-square quadrats. These were taken with a ten-meter skip between each quadrat along two lines west of the abandoned field, at about 100 and 200 feet from the young forest. Results are shown in Table I. The twenty permanent quadrats are of the same size dimension as those taken in the mature forest. They, too, were separated by a skip of ten meters. They are arranged in three lines, representing different distances from the mature forest. Quadrats 1 to 7

TABLE I. Tabulation of woody species in twenty 10-meter-square quadrats in mature stand of *Liquidambar-Acer rubrum-Fagus* type forest, adjacent to area of secondary succession.

Species	Number of stems in seven diameter-classes in inches								
	Below 1 in.	1-2	3-5	6-8	9-15	16-20	Above 20	Total stems	Per cent F.1
Acer rubrum	8	24	24	16	16	4	1	93	75
Acer saccharum	4	3	2		1		1	11	35
Amelanchier canadensis		1	1					2	5
Carpinus caroliniana	29	25	12	1				67	60
Carya laciniosa	6	3	1					10	15
C. ovata	27	18	8	2	2			59	80
Cornus florida	11	4						15	30
Fagus grandifolia	28	44	18	2			3	95	80
Fraxinus americana	19	13	5	4				41	70
Liquidambar styraciflua	1	3	9	5	5	4		27	65
Liriodendron tulipifera		1	1	1	1	1		5	20
Morus rubra	2							2	5
Nyssa sylvatica	1	1	3	2	3			10	25
Ostrya virginiana	16	2	2					20	20
Platanus occidentalis					1			1	5
Prunus serotina	1				1			2	10
Quercus alba	11	5	7	3	3		1	30	70
Q. bicolor				1	1			2	5
Q. borealis var. maxima	4	5	4	2	6	1		22	65
Q. palustris						1		1	5
Sassafras albidum	1		8	11	1			21	55
Ulmus americana	2	7	6	2	1			18	40
Ulmus thomasi		2						2	5
Corylus americana	7							7	10
Lindera benzoin	78							78	20
Smilax glauca	89							89	50
Viburnum dentatum	38							38	35
Vitis sp?	1							1	5

are removed 50 feet from the forest border, quadrats 8 to 15 are removed 100 feet and quadrats 16 to 20 approximately 500 feet. Wooden stakes (24 x 2 x 2) were driven into the ground and the area was delimited by a stout cord supplied with loops at 10-meter intervals. All stems which were at least one inch in diameter were measured by DBH. with wooden calipers and grouped into five size-classes (Table II). All stems less than 1 inch DBH. were tabulated if their height was at least one meter. At the southwest corner of each large quadrat a one-meter quadrat was studied for seedling abundance of woody species (Table II). The plan is to make periodic tabulations of trees in the permanent quadrats to determine the progress and characteristics of the succession.

Results

For summarized data see Tables I to III. In the mature stand *Acer rubrum, Liquidambar styraciflua* and *Quercus borealis* var. *maxima* have the greatest number of stems 9 inches DBH. or over, but associated with them are many other species, important among these are species of *Quercus* and *Carya, Fraxinus americana* and *Fagus grandifolia* (Table I). The most abundant reproduction is evidenced by *Acer rubrum, Carya ovata, Fagus grandifolia, Fraxinus americana* and *Quercus alba.* These species also have the highest per cent of F. I. The association is composed of 19 species of tall trees, 4 of small trees, and 5 shrubs. An unusual feature is that eight species of tall trees have a F. I. of 55 per cent or higher.

The young forest in progress of secondary succession is marked by group segregation tendencies, where invasion and ecesis is a kind of wave-like procedure determined by age of previous invaders. This is plainly shown by difference in stem diameters and abundance of stems of these groups (table III). The first wave is represented by *Acer rubrum* and *Liquidambar styraciflua.* It should be pointed out that these first invaders are still reproducing very vigorously. Replacement of old field species, such as *Juniperus* and *Campsis radicans* is marked. The second wave is represented by *Liriodendron tulipifera, Nyssa sylvatica* and *Prunus serotina.* Representatives of the third wave are *Fraxinus americana, Robinia pseudo-acacia,* and *Ulmus* americana. Four species of *Quercus* participate in the fourth wave. If the mature forest represents the type for the ultimate forest composition of the one developing, then a fifth wave can be expected in which *Fagus,* the various Caryas as well as the second layer trees *Cornus florida, Carpinus caroliniana* and *Ostrya virginiana* will play the leading role. Also, there is still to be expected invasion and ecesis of the characteristic shrubs of the mature forest (table I). While the association is at present dominated by *Acer rubrum* and Liquidambar, indicated increase of competition for crown cover is foreshadowed by a number of other tall tree species (table II). At present the shrub representation is distinctly old field type, such as *Rhus glabra, Vitis labrusca,* and *Campsis radicans.* These will no doubt be eliminated graduallly as succession by trees continues, and as light factors become modified.

TABLE II. Tabulation of woody species according to diameter of stems in inches in twenty 10-meter-square permanent quadrats in area of secondary succession, and 20 one-meter quadrats for seedling study.

Species	Below 1 in.	1	2	3	4	5	Total stems	% F. I.	Total seedlings	Quadrats where found
Acer rubrum	223	199	79	9			510	100	65	1-2-3-5-6-9-10-11-12-13-14-16-17-18-19-20
Acer saccharum	1						1	5		
Carpinus caroliniana	1						1	5		
Catalpa sp. ?	1						1	5		
Cornus florida	2	1					3	5		
Fagus grandifolia	1						1	5	1	11
Fraxinus americana	17						17	55	2	6
Juniperus virginiana	3		1				4	15	1	19
Liquidambar styraciflua	158	175	168	55	16	1	573	100	8	1-5-6-10
Liriodendron tulipifera	55	9	5	1			70	75	5	1-4-5-9-13
Nyssa sylvatica	17	2	2				21	35		
Platanus occidentalis	4	1					5	15		
Populus grandidentata	26	2					28	30	3	9-11-13
Prunus serotina	4	2		1			7	20		
Quercus alba	2						2	10		
Q. bicolor	3						3	10		
Q. borealis var. maxima	1						1	5	4	6
Q. palustris	8						8	5		
Robinia pseudo-acacia	7	1					8	10		
Sassafrass albidum	5	1					6	25	1	7
Ulmus americana	5	1					6	20	13	3-4-6-8-11
					Shrubs					
Campsis radicans	545	1					546	50	36	2-3-4-7-8-9-10-14-15
Parthenocissus quinquefolia									2	5
Rhus glabra	11	1					12	10	1	14
Rhus radicans									14	6-7-11
Rosa sp. ?	2								2	5
Rubus sp. ?									58	1-2-6-9-10-11-12-13-14
Salix sp. ?	63	1					64	35		
Smilax glauca									1	1
Viburnum dentatum var. deamii	21						21	5		
Vitis labrusca	79						79	45	2	10

TABLE III. Number of stems per 10-meter-square quadrat with reference to distance from the parent forest. a. quadrats 1 to 8, about 50 feet distant; b. quadrats 9 to 15, about 100 feet distant; c. quadrats 16 to 20, about 300 feet distant. Stems grouped into three size-classes.

Species		Below 1 inch	1-2 inches	3-5 inches	Total stems
Acer rubrum	a	11.4	24.7	1.0	37
	b	13.0	11.3		24.1
	c	7.4	2.6	.2	10.2
Liquidambar styraciflua	a	10.1	22.0	4.2	36.4
	b	8.1	17.0	1.4	26.5
	c	2.4	9.6	5.6	17.6
Liriodendron tulipifera	a	4.5	2.0	.25	6.7
	b	1.25	.37	.1	1.75
	c	.... .	1.0	... .	1.0
Nyssa sylvatica	a	1.5	.37	. . .	2.0
	b	.7	.....	..	.7
	c	....	.2	.. ..	.2
Prunus serotina	a	.1	. .	..	.1
	b	.25	...	.	.25
	c	..	...	.2	.2
Fraxinus americana	a	.87	.12		1.0
	b	1.1	....	.	1.1
	c		. .	.	...
Ulmus americana	a	.5	... .	. .	.5
	b	.1	.1	....	.2
	c		.	. .	.
Quercus alba	a	.25	. ..	. .	.25
	b	....	...	....	.
	c	..	.. .	..	. .
Q. bicolor	a	.25		..	.25
	b	.12	.....		.12
	c	.. .	. .	. .	
Q. borealis var. maxima	a	...	.		..
	b	.12		.	.12
	c	.....	. ..	..	.. .
Quercus sp. ?	a	.. ..	..	. .	.....
	b	1.0	. ...	.	1.0
	c	.	..		.. .

Distance from the parent forest influences both abundance of stems of migrants (table III) as well as the progress of succession. The set of quadrats (c) which are removed 300 feet from the germule-producing forest have few of the species which constitute the second and third waves of invaders. Also, in the area removed 300 feet from the border of the parent forest 9 species of trees playing a part in the association complex in the mature forest are present while in the lines closer to the forest 14 species are present.

Discussion

Secondary succession is no doubt most involved in areas where the final forest association is most complex (climax or sub-climax). The larger the number of species participating in the crown cover, the more gradual the development in succession will be. In such an association complex there are evidently species exhibiting wide ranges of potentiality to fit into all facets of a habitat, especially also with reference to edaphic factors. In the present case *Fagus* demands better soil moisture conditions than *Liquidambar* and *Acer rubrum.* These latter two species are perhaps better adapted to cope with extremes in old field habitats. The delayed invasion by *Carya* and *Quercus* species may be due to absence of the proper animal relationships, for squirrels would hardly find great attractions to the area now occupied by the young sweet gum-red maple forest. One wonders how the seeds of sweet gum *(Liquidambar)* are carried so far, for lack of any carrying appendages it must be the lightness of the seed which adapts it to wind transportation.

In a simple association, like the one in northern forests, the senior author (4) has pointed out that secondary succession is almost nonexistent, species of the climax, or sub-climax, occupy the vacated habitats almost from the beginning. That early invaders of the climax species must have the potentiality to endure environmental conditions much more severe than those of the climax forest as such was plainly shown by Gates (2) for *Acer saccharum.* This certainly must also be true for the first invaders of the area under study in Versailles Park.

Since succession is to a large extent a habitat control, it is of necessity a complex phenomenon where the elusive microclimate enters in as important factor. It functions as a selective system, which in the area under study permitted successful invasion and ecesis for some species within a period of fifteen years and prevented others, which theoretically should be there, from establishing themselves definitely in the association. The various stages in a succession require many years to reach completion. For a section in Indiana Potzger and Friesner (6) found that after 75 years of progress the final stage had not yet been reached.

The progress of succession in the fallow field at Versailles Park suggests the thought that differences in crown cover in mature forests on similar habitats may frequently be due to differences in migration, and not a habitat selection, when the area was being occupied. It is quite evident that when a crown cover closes it becomes a barrier even to tolerant species. Only death of a dominant tree will create an opening in the crown cover which might be occupied. In a developing even aged stand this may not occur for a century or more. If the oaks and beech are prevented for another 10 to 15 years from invading the area removed 300 feet from the mature forest it appears likely that sweet gum, red maple and tulip poplar will have formed a closed crown cover under which invasion may be impossible. Here would then develop a different forest cover type than in the area which is a few hundred feet closer to the source of seed dissemination, even though habitat conditions otherwise would be alike.

Summary and Conclusions

1. The paper presents a preliminary report on a permanent quadrat study of secondary succession in an Illinoian Tillplain habitat in Versailles State Park, Ripley County, Indiana.

2. The permanent quadrats are twenty 10-meter-square sampling units.

3. On basis of twenty 10-meter-square quadrats an analysis was made of an adjacent mature forest of the Illinoian Tillplain type. In this forest 19 species of tall trees participate in the crown cover. The most important dominants are *Acer rubrum, Liquidambar styraciflua,* and *Quercus borealis* var. *maxima.*

4. Secondary succession on the abandoned field has been in progress for about 15 years. Tree species with great abundance and largest stem diameters are *Acer rubrum* and *Liquidambar styraciflua.*

5. Succession seems to operate as waves of invasion in which always several species are involved. In order of their appearance they are *Acer rubrum* and *Liquidambar; Liriodendron tulipfera, Nyssa sylvatica* and *Prunus serotina; Fraxinus americana, Robinia pseudoacacia* and *Ulmus americana;* four species of *Quercus.* The fifth wave is not yet defined, but it should involve *Fagus* and *Carya* species as well as the second layer trees and several shrubs.

6. While at present the young forest is controlled by *Acer rubrum* and *Liquidambar* there is convincing evidence that many species will eventually participate in the crown control at the close of succession. There is further evidence that the association complex will be like or similar to that existing now in the adjacent mature forest.

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A Study of Variation in Leaf Anatomy with Reference to Habitat in two Species of *Polypodium*

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Introduction

Although ecological anatomy has been extensively investigated in higher plants, comparatively few investigations have been made of anatomical variation as related to habitat in ferns. Two species of *Polypodium*, both occurring in Indiana, exhibit a rather conspicuous habitat diversity which suggested a study of such variation. *P. virginianum* L. normally occurs terrestrially or growing upon rocks, but is rarely an epiphyte. *P. polypodioides* (L.) Watt. var. *Michauxianum*, on the contrary, is usually an epiphyte, being commonly non-epiphytic only near the northern limit of its range, which extends into southern Indiana.

The typically non-epiphytic occurrence of *P. virginianum* is normal for temperate zone vascular plants. The species is, according to Fernald (9), chiefly a northern form, extending from Newfoundland and Manitoba as far south as the mountains of northeastern Georgia. *P. polypodioides*, however, is a tropical form whose close relatives extend throughout South America. Weatherby (15) lists the variety as ranging from Maryland, Illinois, and Missouri southward to Florida, Texas, and Guatemala.

In Indiana, Deam (8, pp. 57-58) reported *P. virginianum* as occurring in fifteen counties exclusively in the western portion of the state and extending its complete length in the north-south direction. Its distribution appears to be correlated with the occurrence of outcrops of sandstone, where it is commonly found near rock ledges. No report of its epiphytic occurrence was given. *P. polypodioides* has been found locally in nine Indiana counties, chiefly in the southern portion of the state in counties bordering the Ohio River. It is roughly limited to the unglaciated area, and has been found only as far north as Monroe County. This fern occurs most frequently on cliff faces and rock surfaces, with only one epiphytic occurrence having been reported.

Studies of variation in leaf anatomy in response to environmental factors have been made by many investigators, including Clements (7), Hanson (10), Pool (14), and Cain and Potzger (5), (6). Although the details of procedure and the plants investigated differ widely in these studies, they are in general accord in finding that leaves from increasingly xeric conditions show a reduction in total leaf size, an increase in thickness, increased development of palisade mesophyll, denser vein network, and usually an increase in stomatal number per unit area. In addition, Cain and Potzger (6) have emphasized the variability encountered between different leaves on the same plant, and even at different locations on the same leaves, with the consequent necessity for the application of statistical techniques to this type of data.

Notations of the rare occurrence of *P. virginianum* as an epiphyte have been made by Fernald (9), Brown (3), and Johnson (11). When epiphytic, it commonly occurs at rather low levels, and usually in relatively protected situations, such as wooded gorges. *P. polypodioides*, on the contrary, has been studied as a typical vascular epiphyte by Andrews (1) and Pessin (13). It occurs on a wide variety of trees and often in relatively unshaded locations. The most favorable substratum is a rough, soft bark with high capacity for water absorption and a low rate of water loss.

In an investigation of microclimatic variation, Baum (2) found the vertical temperature gradient between the 0.5 and 6 foot levels in the summer in the northeastern United States to be the equivalent of a horizontal north-south difference of about 380 miles at the 6 foot level. He suggests that this difference should have an important ecological effect upon vegetation. Terrestrial and epiphytic occurrences of the same species would presumably be influenced by this microclimatic difference.

Material and Methods

Specimens of *P. virginianum* examined in this study were collected at Fern Cliff, Putnam County, 9 miles southwest of Greencastle, Indiana, except for one set obtained along the south bank of the White River in Martin County, approximately 3 miles west of Shoals, Indiana. All specimens of *P. polypodioides* were also obtained from the locality near Shoals with the exception of a single set which was collected at St. George, Dorchester County, South Carolina.

The physical features of the two Indiana localities are remarkably alike. At Fern Cliff, the plants were growing on the cliff face, bordering the south bank of a west fork of Little Walnut Creek. This steep and irregular bluff was cut through the Mansfield sandstone, which outcrops prominently on its face. Since it faces north and is densely wooded, it is relatively moist and heavily shaded. *P. virginianum* is common both on the ground and on the surfaces of the sandstone outcrops. It was, however, found growing epiphytically on only a single tree.

West of Shoals, erosion through the Mansfield sandstone has produced a similar line of north-facing bluffs, near the base of which flows the White River. These are also wooded, and show a comparable luxuriant development of ferns. *P. polypodioides* as well as *P. virginianum* occurs abundantly as dense mats on the surfaces of sandstone outcrops. Only a single tree, however, bore *P. polypodioides* epiphytically.

Growths of foliose lichens were associated with the epiphytic occurrences of both species. The ferns were, however, growing upon the rocks without close associates.

At Fern Cliff, *P. virginianum* was collected from the following three habitats: (1) growing terrestrially in the humus, (2) growing as dense mats on the vertical faces of sandstone outcrops, (3) growing epiphytically at the base and extending upward to a height of three feet upon the north and northeast sides of the trunk of a single beech tree, *Fagus grandifolia.* For purposes of comparison with material from a different area, this species was also obtained from dense mats of plants (4) growing upon the vertical surfaces of north-facing outcrops of sandstone at the Shoals locality. In the table following, these habitats are named as follows: (1) ground, (2) rock-fern Cliff, (3) tree base, (4) rock-Shoals.

TABLE I. Significant Differences[1] Between Means of Measurements of *P. virginianum* Leaves from Different Habitats.

Item Measured	Habitats			
	Rock-Fern Cliff—Ground	Tree base—Rock-Fern Cliff	Tree base—Ground	Rock-Shoals—Rock-Fern Cliff
Length			—	+
Width	—		—	—
Stomatal Number	—		—	+
Upper Cuticle	—	—	—	+
Lower Cuticle			—	
Upper Epidermis				
Lower Epidermis				+
Mesophyll				
Total Thickness				—

[1] + indicates that a significant difference exists, and that the first listed habitat of the compared pair is larger than the second. — indicates that a significant difference exists, the second habitat being larger than the first.

P. polypodioides was collected from the following habitats at the previously described locality near Shoals: (1) growing in dense mats occurring on the vertical surface of sandstone outcrops, (2) growing epiphytically upon the east and south-east sides of the base of the trunk of a single *Fagus grandifolia*, (3) growing epiphytically at a level of approximately fifteen feet upon the east and southeast sides of the same beech tree referred to in (2). *P. polypodioides* was also obtained from a location geographically more typical for the species, at St. George, Dorchester County, South Carolina. The occurrence was, (4), on the southeast side of the trunk of a large live oak, *Quercus virginiana*, in a relatively unshaded location. Material was collected from the trunk at a height of approximately six feet. A dense growth of moss was present about the roots of the plants. These habitats are named in the following table as (1) rock, (2) tree base, (3) tree-15′, (4) tree-S. C.

Measurement of gross dimensions was made on sets of 25 leaves from each habitat selected at random insofar as possible. All material was collected in the late fall or winter, so that fully developed leaves were obtained. Length was measured from rhizome to leaf tip, width at the basal lobes of the deeply incised leaf where this dimension was at a maximum.

Stomatal frequency was determined by examination of 25 leaves of each species, selected at random from each habitat. The pair of lobes second from the base of each leaf was arbitrarily selected for study; the number of stomata was counted in each of 4 microscopic fields distributed from the base to the tip of left and right lobes, alternately, of this pair, giving a total of 100 fields examined per habitat. The lower epidermis was removed from leaves of *P. virginianum* for study, while examination was made of strongly illuminated whole mounts of lobes of *P. polypodioides.*

For the study of leaf tissues, samples of 25 leaves were chosen at random from each habitat for each species. In order to obtain comparable samples from each leaf, the pair of lobes second from the base of the leaf was again arbitrarily selected. Samples were obtained by cutting small sections alternately from the left and right lobes of this pair, and perpendicular to the midvein at a distance of approximately 1 cm. from the rachis.

TABLE II. Significant Differences[1] Between Means of Measurements of *P. polypodioides* Leaves from Different Habitats.

Item Measured	Habitats			
	Tree base Rock	Tree-15′— Tree base	Tree-15′— Rock	Tree S.C.— Tree-15′
Length	—	—	—	+
Width		—	—	+
Stomatal Number	—	+	—	
Upper Epidermis	+	—		
Lower Epidermis	+	—		
Palisade Tissue				+
Spongy Mesophyll			—	+
Total Thickness				+

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[1] + indicates that a significant difference exists, and that the first listed habitat of the compared pair is larger than the second. — indicates that a significant difference exists, the second habitat being larger than the first.

The samples so obtained were killed and fixed in formalin-acetic-alcohol, embedded in paraffin, sectioned at 10 microns, and stained with safranin and fast green. Tissue thicknesses were measured at right angles to the upper leaf surface at a distance of approximately 250 microns from the midvein. Measurements were made by means of an ocular micrometer.

The data thus obtained were treated by standard statistical procedures. For each set of measurements, the mean, standard deviation, standard error, and coefficient of variation were calculated. In comparing sets of measurements, the difference, standard error of the difference, and significance ratio were determined. Differences were considered significant at the 2% level of confidence, corresponding to a significance ratio of 2.49.

Measurements at regular intervals of the physical factors of the environment such as light, temperature, rainfall, and humidity for each habitat over an extended period are desirable for a study of this nature. Because of the distances to and between the localities involved, and the necessity for such measurements to be made during the spring and summer months, this data could not be secured. This limitation must be considered in examining the results of this study.

Description

The leaves of *P. virginianum* are simple but deeply pinnatifid, being divided into opposite to sub-opposite, linear-oblong lobes which have entire or slightly toothed margins. The lobes vary in number from approximately 5 to 50, depending on the length of the leaf.

The leaves are somewhat coriaceous and are evergreen. Under conditions of moisture deficiency they undergo curling which leaves the lower, stomata-bearing surface exposed.

Both upper and lower leaf surfaces appear glabrous to the naked eye, but microscopic examination shows that a limited number of hairs are present on the lower epidermis. These hairs are typically multicellular, being composed of a narrow, elongate basal cell and a bulbous terminal cell. The hairs are about 250 microns long. Stomata are present only on the lower epidermis, which is loosely attached to the mesophyll. A continuous cuticle is present on both upper and lower leaf surfaces. No palisade is differentiated.

The leaves of *P. polypodioides* are also simple and deeply pinnatifid, with linear-oblong lobes extending nearly to the petiole. The leaves are coriaceous and evergreen. The lobes have entire margins, and are typically both thicker and smaller than those of *P. virginianum*. A range in total number of lobes per leaf of from 3 to 33 was observed from leaves of varying lengths. Stomata are borne only on the lower epidermis. The mesophyll is differentiated into both spongy and palisade tissue.

While the upper leaf surface is glabrous, the lower surface and the petiole are in large part covered with brownish, orbicular to deltoidovate, peltately attached scales. These scales are multicellular, and consist of a basal portion sunk into the lower leaf surface, an outwardly tapering stalk, and a terminal plate-like portion. The scales are variable in size, but combine to cover a major portion of the lower surface, imparting to it a grayish-brown color.

The cuticle displays a seeming lack of regularity, no cuticle being apparent on some portions of the epidermis, while on others it is well-developed. It is not possible to report this as a typically occurring situation on the basis alone of the examination made in connection with this study. However, the cuticle could not be reliably measured for this species in the material examined, and therefore has not been included.

Under dry conditions, the leaves of *P. polypodioides* undergo a characteristic curling, unrolling when moisture again becomes available. The margins of each lobe are folded inward, and at the same time the lobe rolls inward toward the petiole from the end. The entire leaf also curls over toward its base. All curling is in a manner which leaves the lower, scale- and stomata-bearing surface outwardly exposed.

Results and Discussion

Although it is not possible to present here complete tables of the data for each leaf dimension measured[1] the occurrence of significant differences between means of the various measurements from the habitats compared are compiled in Table I for *P. virginianum*, and in Table II for *P. polypodioides*.

Of the *P. virginianum* habitats at Fern Cliff, decreases in both length and width occur in the same order of habitats, ground, rock, and tree-base. Significant differences occur in widths in two habitat pairs, while differences in length are significant only between the tree-base and ground habitats. There seems to be a tendency toward reduction in leaf size between the ground and tree habitats, with the rock location intermediate in this respect.

Comparison of the similar rock habitats at the separate localities for this species, however, reveals a significant difference in length, 6.24 cm., which is nearly three times as great as the difference of 2.38 cm. existing between the most highly contrasting habitat pair, tree base—ground, at Fern Cliff. The opposite is true of the width, since the mean measurement from the rock-Shoals location, 3.97, is smaller than that from any of the Fern Cliff habitats, and significantly so in comparison with the rock habitat there. This apparent anomaly is difficult to explain in terms of ecological variation though real enough, for the leaf presents a long, slender appearance which is distinctive even to casual observation. The species tends to be polytopic in Indiana, since the outcrops of sandstone on or near which it is found are discontinuous. The possibility of slightly differing characters occurring in separate locations quite apart from ecological variation would thus seem to exist. At any rate, the total leaf area, the important factor to which both length and width relate, is increased by the large increase in length to a degree which renders the width decrease comparatively unimportant, whatever its cause.

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[1] For complete data, see unpublished thesis, DePauw University, Greencastle, Indiana.

The leaf of *P. virginianum* is thus seen to show significant variation in both length and width, and consequently in total leaf area. These size variations are conspicuously smaller between contrasting habitats at the same location than they are from two similar habitats at different locations.

Leaves of *P. polypodioides* from contrasting habitats at Shoals also show a regular order of decrease, rock, tree-base, and tree-15′, in both length and width. The differences are significant between all pairs for length, and for all but tree base—rock for width, and indicate a decrease in total leaf size with the listed order of habitat change. The epiphytic *P. polypodioides* from South Carolina is significantly both longer and wider than either of the Shoals epiphytes.

As was the case with *P. virginianum* at Fern Cliff, *P. polypodioides* at Shoals shows variability in size of leaf between contrasting habitats. Size differences between occurrences similarly in being epiphytic, but geographically separate, are, however, greater for width and as great for length than those from the same geographic location.

Incidence of stomata, while at times showing variation to a significant degree in both species, as shown in Tables I and II, does not form an indicative pattern. It increases in number, for example, with increase in leaf size in *P. polypodioides* between the tree-15′ and the rock habitats, and increases in number with the decrease in leaf size in the same species between the tree-15′ and the tree-base habitats. Consequently, as has been noted by Miller for other plants (12, p. 418), the number of stomata does not appear to be a clear-cut variable of increasingly xeric conditions.

The cuticle, which, as noted earlier, was measured only in *P. virginianum*, regularly shows significant changes between habitats. Because of its high degree of variability within a given habitat (coefficients of variation are about 20%), it seems worthwhile only to note that in general the upper cuticle seems to be influenced more by habitat contrasts than is the lower.

No individual tissues from leaves of *P. virginianum* from contrasting habitats showed differences in thickness great enough to be significant. Although the significance ratio for the sum of the individual leaf tissues, total leaf thickness, was rather high, it did not reach the 2% level of confidence. Consequently the gross leaf measurements, for which significant differences do exist, have been, apparently, more responsive to the environmental contrasts between the habitats at Fern Cliff than were the internal tissues, particularly the mesophyll, which is normally the most variable of the leaf tissues.

That variation can exist in mesophyll thickness in *P. virginianum*, however, is shown by the significant difference in means between the rock occurrences at the separate Fern Cliff and Shoals localities (Table I). This increase in mesophyll at Shoals is also reflected in a significant difference in total leaf thickness between the two habitats. As was the case for gross measurements, greater variability of both mesophyll and total leaf thickness is found between similar habitats which are geographically separate than between contrasting habitats at the same locality.

Leaf tissues of *P. polypodioides* from the habitats at the Shoals locality, while showing some slight variation, reached the level of significance only for the relatively thin epidermis from two habitat pairs, and for the spongy mesophyll, which was thicker in the rock than in the tree-15′ location (Table II).

Internal structure of leaves from the epiphytic occurrence in South Carolina, on the other hand, contrasts greatly with that of leaves from the Shoals locality. There is a greatly increased development of both palisade and spongy mesophyll, resulting in significant increases of thickness, both of these tissues and of total leaf thickness.

As was also found for gross measurements, thicknesses of leaf tissues are more constant for the differing habitats at a single locality than between epiphytic habitats at different localities.

In both species, more variation occurred in gross measurements between differing habitats at the same locality than did in the thicknesses of component leaf tissues. Leaf size, particularly length, probably due to continued apical growth, seems to be more responsive to differences in environmental factors than is the development of leaf tissues.

The relatively smaller amount of variation in leaf anatomy previously noted in each species from contrasting habitats at the same geographic locations, compared to the contrast between plants from similar habitats at separated locations suggests that contrasts in environmental factors are greater due to geographic separation than to vertical distribution in the occurrences studied for each plant. The existence of this situation seems plausible in the present instance, since, it will be recalled, both the Fern Cliff and Shoals localities are rather specially situated and similar north-facing bluffs, moist, shaded, and highly protected. It seems possible that the rare epiphytic occurrence of these ferns so far north is dependent upon the existence of special conditions under which the environmental factors, other than the actual nature of the substratum, are not sufficiently different from those of the normal ground or rock habitats to bring about the ecological variation in anatomy of which the leaves of these plants are capable.

In the absence of measurements of environmental factors, no specific conclusions can be drawn as to the type of conditions producing these variations. However, there is no apparent reason to believe them different from those producing similar responses in other plants. From the data presented, it is apparent that a considerable degree of plasticity exists in the response to environmental conditions exhibited by the two species of *Polypodium* considered. In general, this response is similar to that typical of higher plants, with decrease in total leaf size accompanied by a relative increase in thickness, principally of the palisade and spongy mesophyll.

Summary

1. In this paper, the variation in leaf anatomy of two fern species, *P. virginianum* and *P. polypodioides,* has been examined. For each species, samples of 25 leaves from each of three different habitats, including both terrestrial and epiphytic occurrences, were obtained from the same location. A comparison was also made for each species to one similar habitat at a geographically separate location.

2. Gross leaf dimensions, stomatal number, and thickness of the various leaf layers were measured for each species. Standard statistical procedures were applied to the data thus obtained.

3. Results indicate that these ferns exhibit variation in leaf anatomy similar in both degree and direction to that previously reported for higher plants. Leaf size, as shown principally by length of leaf, apparently is modified by environmental differences which are not sufficient to affect significantly the thickness of the leaf layers.

4. Variation in leaf anatomy is found to be more pronounced between the ecologically similar but geographically separate habitats, than it is between the contrasting but adjacent habitats which were compared. It is therefore suggested that the normally rare (in Indiana) epiphytic occurrence of these two species may be in this instance related to the location of host trees in special habitats where the normal vertical gradient of increasing xeric conditions is decreased.

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Notes on Indiana Liverworts—III. Some New County and State Records

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During the summer of 1947 and again in 1949 the writer visited several Indiana counties in which little or no liverwort collecting had been done. These counties are in the eastern central and in the southeastern part of the state. The new county records found on these trips together with some collections by Dr. Friesner in Clay county and a few miscellaneous collections are reported here.

Cephalozia bicuspidata (L.) Dum. Ripley Co.: on rotten wood, creek along route 129, July 18, 1949, Wagner 2461, 2462. This species has been reported previously in Indiana only from Parke county.

C. pleniceps (Austin) Lindb. Parke Co.: on sandy soil, along Sugar Creek, Turkey Run State Park, Sept. 4, 1946, Wagner 1327; on sandstone, along Sugar Creek, Turkey Run State Park, Sept. 4, 1946, Wagner 1318. This is a new state record.

Cephaloziella hampeana (Nees) Schiffn. Ripley Co.: on rotten wood, stream along route 129, July 18, 1949, Wagner 2463. A minute species formerly reported in Indiana from three counties.

Chiloscyphus pallescens (Ehrh.) Dum. Dearborn Co.: on soil, mixed with *Hypnum*, 1 mile southwest of Dillsboro, July 18, 1949, Wagner 2403. Ripley Co.: on rotten log, stream along route 129, July 18, 1949, Wagner 2407.

Cololejeunea biddlecomiae (Austin) Evans. Union Co.: on bark, woods 4 miles north of Liberty, June 8, 1947, Wagner 1409. This species has not been found in Indiana north of Madison county.

Conocephalum conicum (L.) Dum. Brown Co.: on soil along stream, Brown County State Park, June 8, 1947, Wagner 1429. Clay Co.: on sandstone cliff along route 40 near Harmony, Sept. 19, 1946, Friesner 21246. Huntington Co.: Oct., 1946, Fred Loew. A very common species in damp habitats, especially around water falls. It grows on both limestone and sandstone, and is known from 33 counties in Indiana.

Frullania eboracensis Gott. Blackford Co.: on tree trunk, woods 6 miles northwest of Pennville, June 4, 1947, Wagner 1403. Dearborn Co.: on black locust, 3 miles east of Dillsboro, July 18, 1949, Wagner 2404. Jay Co.: on tree, 2 miles north of Red Key, June 4, 1947, Wagner 1422. Ohio Co.: on tree trunk, along route 262 northwest of Rising Sun, July 18, 1949, Wagner 2448. Ripley Co.: on rotten log along route 129, July 18, 1949, Wagner 2432, 2434. Known from 39 counties in Indiana, it is one of the most common liverworts growing on tree trunks. It may be found in relatively dry localities, and probably could be collected in every county in Indiana.

F. riparia Hampe. Brown Co.: on tree bark, Brown County State Park, June 9, 1947, Wagner 1433. Randolph Co.: with moss, 8 miles south of Union City, June 8, 1947, Wagner 1404. Switzerland Co.: on sycamore bark, 3 miles east of Florence, July 18, 1949, Wagner 2447, 2458. Wells Co.: on bark, woods 3 miles west of Poneto, June 4, 1947, Wagner 1418. In this species, nearly all of the lobules are explanate.

F. squarrosa (R. Bl. & Nees) Dum. Ripley Co.: on rotten bark, stream along route 129, July 18, 1949, Wagner 2433, 2437, 2439. Rather infrequent in Indiana, it has been reported from 9 counties. It is easily recognized by its large size and the way the leaves roll tightly around the stem when dry. When moist, the leaves are squarrose-spreading.

Lophocolea heterophylla (Schrad.) Dum. Blackford Co.: on decayed wood, 6 miles northwest of Pennville, June 4, 1947, Wagner 1401. Brown Co.: on humus, Brown County State Park, June 8, 1947, Wagner 1423. Dearborn Co.: on soil with mosses, 1 mile southwest of Dillsboro, July 18, 1949, Wagner 2402, 2405, 2445. Jay Co.: on decayed wood, 2 miles north of Red Key, June 4, 1947, Wagner 1420. Ripley Co.: on rotten log, along route 129, July 18, 1949, Wagner 2446, 2450. Common throughout Indiana on rotten wood and clay banks; known from 39 counties.

Nowellia curvifolia (Dicks.) Mitt. Ripley Co.: on rotten log over stream, along route 129, July 18, 1949, Wagner 2400.

Pellia epiphylla (L.) Corda. Clay Co.: on sandstone cliff, one half mile northeast of Harmony, Sept. 19, 1946, Friesner 21245. This species has not been reported in Indiana from any county north of Delaware and Warren. It would seem that it might be collected frequently in the lake country of northern Indiana.

Plectocolea hyalina (Lyell) Mitten. Ripley Co.: on rotten wood, stream along route 129, July 18, 1949, Wagner 2401.

Porella pinnata L. Switzerland Co.: in mud at tree base, 3 miles east of Florence, July 18, 1949, Wagner 2458. Reported from 8 counties in Indiana, none north of Randolph. It is found most frequently in areas which are inundated more or less regularly; occasionally it is found growing continuously submerged.

P. platyphylla (L.) Lindb. Blackford Co.: in woods, 6 miles northwest of Pennville, June 4, 1947, Wagner 1402. Brown Co.: on tree base, Brown County State Park, June 8, 1947, Wagner 1431. Dearborn Co.: on limestone, 1 mile southwest of Dillsboro, July 18, 1949, Wagner 2444, 2449. Jay Co.: in woods 2 miles north of Red Key, June 4, 1947, Wagner 1420. Ohio Co.: on hickory, along route 262, northwest of Rising Sun, July 18, 1949, Wagner 2406. Posey Co.: May 13, 1934, W. H. Welch 7820. Ripley Co.: on bark, along route 129, July 18, 1949, Wagner 2418; on limestone, Wagner 2459. Union Co.: on tree base, woods 4 miles north of Liberty, June 8, 1947, Wagner 1408. Known in Indiana from 46 counties.

Preissia quadrata (Scop.) Nees. Brown Co.: on damp hillside, Brown County State Park, June 9, 1947, Wagner 1431.

Reboulia hemisphaerica (L.) Raddi. Brown Co.: on soil with moss, Brown County State Park, June 8, 1947, Wagner 1425.

Riccardia palmata (Hedw.) Carruth. Parke Co.: on rotten log at Wedge Rock, Turkey Run State Park, Sept. 4, 1946, Wagner 1332. This is a new state record.

Scapania nemorosa (L.) Dum. Brown Co.: on soil along stream, Brown County State Park, June 9, 1947, Wagner 1432.

This report removes seven Indiana counties from the list of those in which no liverworts have been collected, leaving twenty yet untouched. The total number of species now known to occur in Indiana is seventy-three. The specimens mentioned in this paper are deposited in the DePauw University Herbarium.

Studies in Indiana Bryophytes VII

WINONA H. WELCH, DePauw University

The mosses used in this study are Indiana collections in herbaria in the following institutions: Butler University, Chicago Natural History Museum, Carnegie Museum, DePauw University, University of Michigan, University of Minnesota, New York Botanical Garden, Laboratoire de Cryptogamie, Muséum d'Histoire Naturelle, Paris, France, and University of California, Berkeley.

The asterisk following the name of the plant indicates that this is the first known published record of this species or variety in Indiana.

Research grants from the Penrose Fund of the American Philosophical Society, the Indiana Academy of Science through the American Association for the Advancement of Science, and the Graduate Council of DePauw University have made possible the study of the plants herein described.

FONTINALACEAE (WATER MOSSES)

Plants normally submerged but frequently exposed by recession of the water, attached at base of stems by rhizoids; stems flaccid to rigid, short to much elongated, up to 150 cm. in length, 0.2-0.75 mm. in diameter, often denuded at or near the base with age, regularly or irregularly branched; branches erect-ascending to spreading, ends of foliated stems and branches acuminate to obtuse, in some species conspicuously three-angled, frequently curved to uncinate in *Dichelyma;* leaves tristichous, flaccid to firm, erect to spreading, often secund, subfalcate to falcate, or uncinate in *Dichelyma*, plane, subconcave to concave, subcanaliculate to canaliculate, irregularly longitudinally folded, faintly keeled, subcarinate, or carinate-conduplicate, keel straight to strongly curved, ecostate in *Fontinalis*, costate in *Dichelyma* and *Brachelyma* with the single midrib supercurrent to long excurrent, plane or unfolded blades subulate, lanceolate-subulate, sublanceolate, lanceolate, oblong-, ovate-, oval-, or subelliptic-lanceolate, subovate to ovate, suboval to oval, suborbicular, or subrhomboidal to rhomboidal, apices subulate, short to long acuminate, subacute to acute, subobtuse to obtuse, sometimes subcucullate to cucullate, occasionally subcymbiform, entire to serrulate, margins of apices sometimes narrowly to broadly involute, blades 2-10 mm. long, 0.35-8.5 mm. wide; median cells of leaves subrhombic, subrhomboidal, subhexagonal, linear-rhomboidal, linear-rhombic, or linear, ends obtuse or attenuate, frequently cells subflexuous to flexuous; marginal cells occasionally forming a border; alar cells not enlarged to much enlarged, subquadrate to subhexagonal; auricles distinct to none; leaf bases not decurrent to long decurrent; dioecious usually; sporophytes on upper portion of stem in *Brachelyma* and *Dichelyma* and on the lower part in *Fontinalis;* perichaetium suboval to cylindrical; calyptra long conical or mitriform, dimidiate in *Dichelyma* and *Brachelyma*; capsule sesile, subsessile, or on short to moderately long seta; operculum obtuse conical in *Fontinalis*, rostrate in *Dichelyma* and *Brachelyma;* seta 0.1-1.5 mm. long in *Fontinalis* and *Brachelyma*, 3-21.5 mm. in length in *Dichelyma;* urn suboval to cylindrical, 0.65-3 mm. long, 0.35-2 mm. in diameter; peristome double, teeth 16, free or united in pairs at apices, cilia 16, free or incompletely to completely united by transverse strands into a conical trellis; spores 10-35μ in diameter, ripe in summer.

Since *Dichelyma* and *Fontinalis* are known to occur in Wisconsin, Michigan, and Ohio, and *Brachelyma* and *Fontinalis* in Illinois, the key includes the three genera of Fontinalaceae although at present only *Fontinalis* has been recorded from Indiana. It seems probable that many of the species in the states bordering Indiana may be found, sometime, in Indiana. These species have been included in the keys in addition to those known to occur in the state.

Key to the Genera of Fontinalaceae

1. Leaves ecostate, from plane to concave, tubular, or carinate-conduplicate; perichaetium oval, oblong, or cylindrical; perichaetial leaves oblong, ovate, oval, oval-lanceolate, or orbicular; calyptra conical; capsule immersed in perichaetial leaves or emergent . . . . *Fontinalis.*
1. Leaves costate, always carinate-conduplicate; perichaetium always cylindrical; perichaetial leaves ovate-lanceolate, elliptic-lanceolate, or linear-lanceolate; calyptra dimidiate.
    2. Ends of foliated stems and branches conspicuously three-angled, not curved or uncinate; leaves not secund; keel straight to moderately curved, frequently abruptly curved near apex; calyptra covering operculum only; capsule completely immersed; seta 0.75-1.5 mm. long . . *Brachelyma.*[1]
    2. Ends of foliated stems and branches not conspicuously three-angled, commonly slightly to distinctly curved, frequently uncinate; leaves often secund and falcate; calyptra enveloping capsule; capsule emergent to surpassing perichaetium; seta 3-21.5 mm. long . . . . *Dichelyma.*

Key to Species of Fontinalis[2]

1. Leaves usually carinate or carinate-conduplicate.
    2. Leaves with keels or median lines predominantly curved above basal curve.

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[1] *Brachelyma subulatum* has been collected in Illinois.

[2] All references concerning leaves are applicable to the majority of median cauline blades unless otherwise stated. The leaf shapes are those of unfolded blades. The ratios recorded are to be interpreted as length to width.

- 3. Leaves broadly ovate or ovate-lanceolate, oval, or suborbicular, 4-8 mm. long, 3-6.5 mm. wide, 1-1.6:1; keels moderately curved to almost semicircular; plants robust . . . . *F. antipyretica* var. *gigantea.*
- 3. Leaves ovate- to oval-lanceolate, 3-8.5 mm. long, 2-4 mm. wide, 1.5-3.5:1; keels slightly to moderately curved; plants medium in size . . . . *F. antipyretica.*

2. Leaves with keels or median lines predominantly straight above basal curve, frequently abruptly curved at apex; apices briefly and broadly acuminate, often subconcave to plane; blades ovate- to broadly ovate-lanceolate, 4-6 mm. long, 1.5-2.5 mm. wide, 1.5-3:1; plants medium to robust *F. patula.*

1. Leaves usually concave.
  - 2. Leaves erect to slightly erect-spreading, appearing to be appressed; apices of perichaetial leaves acute or apiculate . . . . *F. dalecarlica.*
  - 2. Leaves erect-spreading to spreading, not appearing to be appressed; apices of perichaetial leaves usually broadly obtuse or rounded.
    - 3. Margins frequently involute.
      - 4. Margins in apical portions commonly narrowly involute.
        - 5. Blades usually firm, ovate-lanceolate, and 2.5-4 mm. long, 1-2 mm. wide . . . *F. novae-angliae*
        - 5. Blades usually flaccid, broadly ovate-lanceolate, and 4-7.5 mm. long, 1.5-3.5 mm. wide . . . . . . *F. novae-angliae* var. *latifolia.*
      - 4. Margins in apical portions frequently broadly involute, the broad involution sometimes extending to base of blade, occasionally margins convolute and blades subtubular to tubular.
        - 5. Apices long acuminate; apical cells rhombic, rhomboidal, quadrat, rectangular, or hexagonal; blades narrowly ovate-lanceolate (aestival leaves) *F. biformis.*
        - 5. Apices generally obtuse to truncate, margins gradually narrowing to tips; apical cells linear or linear-rhomboidal; blades ovate- or oblong-lanceolate or lanceolate . *F. novae-angliae* var. *cymbifolia.*
    - 3. Margins not involute.
      - 4. Apical cells rhomboidal, rhombic, quadrate, rectangular, or hexagonal; apices narrowly to broadly obtuse; blades broadly ovate-lanceolate or lanceolate . (vernal leaves) *F. biformis.*
      - 4. Apical cells linear or linear-rhomboidal; apices acuminate, frequently serrulate.

        5. Stems flaccid; leaves usually subflaccid, lanceolate to ovate-lanceolate . . . . . . *F. missourica.*
        5. Stems rigid; leaves firm, narrowly lanceolate.
            6. Blades concave throughout or subconcave at base and plane above, occasionally canaliculate to subtubular; apices narrowly acuminate; leaves 0.75-1.5 mm. wide . . . . *F. disticha.*
            6. Blades concave or deeply concave to convolute tubulose; apices long acuminate or subulate; leaves 0.35-0.5 mm. wide *F. filiformis.*

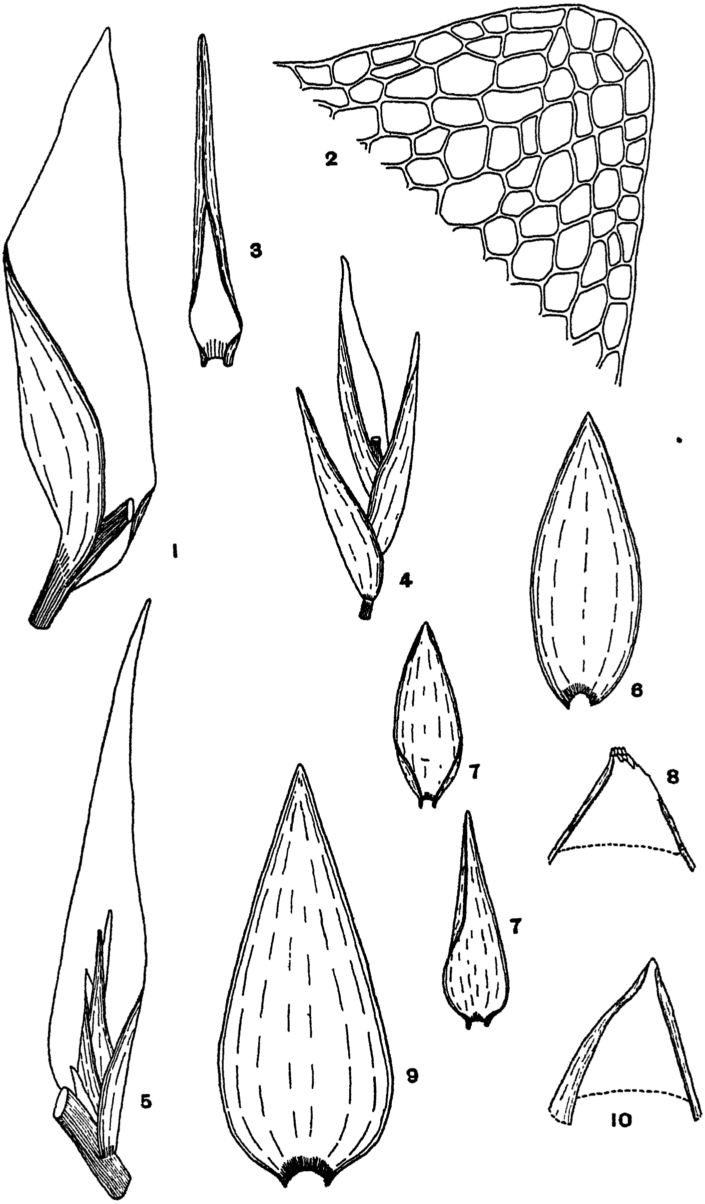
1. Leaves usually plane.
    2. Leaves generally broadly ovate-lanceolate or oval-lanceolate, 1-2.5 mm. wide; margins tapering from approximate middle into apex; apices short and broadly acuminate; auricles frequent . . . . *F. Duriaei.*
    2. Leaves generally narrowly ovate-lanceolate or lanceolate, 0.5-1.75 mm. wide; margins tapering from basal fourth or half into apex; apices long acuminate.
        3. Apices gradually narrowed; tips commonly acute and entire; auricles usually none, occasionally very slight *F. hypnoides.*
        3. Apices frequently abruptly narrowed; tips commonly obtuse to truncate and serrulate; auricles very conspicuous *F. flaccida.*

Key to Species of Dichelyma

1. Costa subpercurrent to briefly excurrent.
    2. Costa frequently briefly excurrent; leaf apices subulate or acuminate . . *D. falcatum.*
    2. Costa not excurrent; leaf apices often subobtuse or obtuse . . . . *D. pallescens.*
1. Costa long excurrent *D. capillaceum.*

Indiana Species of Fontinalis

F. biformis Sull.* (Figs. 1-3.) Plants medium in size in spring and approaching slender in summer and autumn, up to 67.5 cm. in length, with two distinct kinds of leaves during one growing period, vernal stage yellowish green, green or brownish green, aestival phase brownish green or blackish; vernal median cauline leaves with bases up to 1.5 mm. apart, blades flaccid, erect-spreading, concave to plane, usually broadly ovate-lanceolate, sometimes lanceolate; apices broadly acuminate, leaf tips usually narrowly to broadly obtuse, sometimes subobtuse to acute, commonly subserrulate to serrulate, sometimes entire; median cauline leaves 4-7.5 mm. long, 1.25-3.5 mm. wide, 2.5-4:1; median cells of leaves linear; apical cells rhomboidal, rhombic, subquadrate, subrectangular, or subhexagonal, somewhat sphagniform; auricles distinct; aestival median cauline leaves very different in appearance from the former, occurring with the vernal and eventually composing the dominant foliage of the plants for a period, occasional young or vernal leaves sometimes present, bases of blades up to 1.5 mm. apart, leaves firm, erect-spreading, usually concave, canaliculate or subtubular, sometimes subconcave to plane,



margins involute to convolute, blades narrowly ovate-lanceolate; apices long acuminate, leaf tips acute, generally serrulate, sometimes entire; median cauline leaves 2-3.5 mm. long, 0.4-0.8 mm. wide, 3-7.5:1; median cells of leaves linear; apical cells rhombic, rhomboidal, subquadrate, subrectangular, or subhexagonal, somewhat sphagniform; auricles distinct. Specimens studied from Owen and Putnam counties.

F. dalecarlica Br. and Schimp.* (Fig. 4.) Plants slender, up to 90 cm. in length; branches numerous, frequently appearing fasciculate, ends of foliated stems and branches attenuate; median cauline leaves subimbricate to imbricate, bases up to 1 mm. apart, blades firm, erect to slightly erect-spreading, concave, ovate-lanceolate, narrowly ovate-lanceolate, or narrowly lanceolate, margins occasionally slightly involute in apical portions; apices usually acute or acuminate, leaf tips entire or serrulate; blades 2-4.75 mm. long, 0.5-1.5 mm. wide, 3-4.5:1; median cells of leaves linear with ends attenuate; auricles usually distinct. Specimens studied from Lawrence and White counties.

F. disticha Hook. and Wils.* (Fig. 5.) Plants slender in size; stems subrigid to rigid, up to 25 cm. in length; branches generally somewhat rigid, spreading or erect-spreading, usually close, appearing to be distichous in herbarium specimens although tristichous, short, up to 5 cm. long, ends of foliated stems and branches attenuate; leaves distant, bases up to 2 mm. apart, blades generally firm, erect to spreading, commonly concave, occasionally canaliculate to subtubular, narrowly lanceolate; apices long and narrowly acuminate, leaf tips usually acute to subacute, generally serrulate or subserrulate, occasionally entire; median cauline leaves commonly 4-6.5 mm. long, sometimes up to 9 mm. in length, 0.75-1.5 mm. wide, 3.7-8:1; median cells of leaves linear with ends attenuate; auricles usually distinct. Specimens studied from Knox county.

F. Duriaei Schimp.* (Fig. 6.) Plants slender to medium in size, sometimes rather delicate; stems flaccid, up to 30 cm. in length; branches few to numerous, up to 12 cm. in length, ends of foliated stems and branches attenuate; median cauline leaves usually distant, bases 2-2.5 mm. apart, blades flaccid to somewhat firm, erect-spreading to spreading, usually plane, sometimes with one to two slight longitudinal folds, generally broadly ovate-lanceolate or oval-lanceolate, sometimes oblong-lanceolate, width decreasing either gradually or somewhat abruptly from the approximate middle into the apex; majority of apices short and broadly acuminate, leaf tips usually acute, occasionally subobtuse, commonly serrulate, often entire; median cauline blades 3-7 mm. long, 1-2.5 mm. wide, 2-5.5:1; median cells of leaves usually linear with ends attenuate, sometimes narrowly rhomboidal; auricles distinct to none. Specimens examined from Elkhart, Fulton, Lake, and Pulaski counties.

F. novae-angliae Sull.* (Figs. 7-8.) Plants commonly medium in size; stems up to 40 cm. in length; branches numerous, up to 11 cm. in length, ends of foliated stems and branches usually attenuate; median cauline leaves with bases 0.5-2 mm. apart, blades usually firm, erect to erect-spreading, concave, commonly ovate-lanceolate, sometimes oblong-lanceolate or narrowly ovate-lanceolate, margins in apical portions of blade generally narrowly involute, occasionally plane; apices commonly subtruncate, truncate, subobtuse, or obtuse, sometimes subacute to acute, at times almost cucullate, leaf tips usually distinctly serrulate, occasionally entire; median cauline blades 2.5-6 mm. long, 0.75-2.5 mm. wide, 1.75-5:1; median cells of leaves linear with ends attenuate or narrowly rhomboidal, cells above basal area commonly subflexuous or flexuous; auricles distinct, leaf bases occasionally subclasping. Specimens studied from Crawford and Perry counties.

F. novae-angliae Sull. var. *latifolia* Card.* (Figs. 9-10.) Median cauline leaves with bases 1-2 mm. apart, blades subflaccid to flaccid, broadly ovate-lanceolate, 4-7.5 mm. long, 1.5-3.5 mm. wide, 2-3:1; otherwise plants similar to those of *F. novae-angliae.* Specimens studied from Putnam county.

The drawings, made by William D. Gray, are those used by the author in the treatise on the Fontinalaceae in Grout, Moss Flora of North America North of Mexico 3: pls. 73-79. 1934.

Fontinalis biformis. Fig. 1. Median cauline leaf (vernal stage), enlarged, (Sullivant, Icon. Musc. pl. 60). Fig. 2. Apical cells of same, X 255. Fig. 3. Median cauline leaf (aestival stage), enlarged, (Sullivant, Icon. Musc. pl. 60). *Fontinalis dalecarlica.* Fig. 4. Portion of stem with median cauline leaves, enlarged, (Bruch and Schimper, Bry. Eur. pl. 431). *Fontinalis disticha.* Fig. 5. Median cauline leaf, enlarged, (Sullivant, Icon. Musc. pl. 63). *Fontinalis Duriaei.* Fig. 6. Median cauline leaf, X 8.5. *Fontinalis novae-angliae.* Fig. 7. Median cauline leaves, X 8.5. Fig. 8. Leaf apex, enlarged. *Fontinalis novae-angliae* var. *latifolia.* Fig. 9. Median cauline leaf, X 8.5. Fig. 10. Leaf apex, X 59.

CHEMISTRY

Chairman: W. G. Kessel, Indiana State College

Keith Seymour, Butler University, was
elected chairman for 1950

ABSTRACTS

Iodine Trichloride as a Chlorinating Agent. E. Campaigne and Wayne E. Thompson, Indiana University.—This is a preliminary report, describing some remarkable results obtained when iodine trichloride is allowed to react with certain aliphatic and aromatic organic compounds, and tentatively suggesting a possible explanation of these results. Crystalline iodine trichloride reacts violently with an equimolar portion of benzene in carbon tetrachloride to produce 61% of the theoretical amount of o-dichlorobenzene, and only 9% of the expected monochlorobenzene. No p-dichlorobenzene was obtained. Even when a ten-fold excess of benzene was used, the principle product was o-dichlorobenzene. In addition, some pure 1, 2, 4, 5-tetrachlorobenzene, uncontaminated by other tetrachloro-derivatives, was found, and also a small amount of hexachlorobenzene. Anisole reacted with iodine trichloride to give as the principle product 3, 4-dichloroanisole. Butanoyl chloride yielded 2, 3-dichlorobutanoyl chloride as the only chlorination product.

The stoichiometry of this reaction seems to be:

$$C_6H_6 + 2ICl_3 \rightarrow C_6H_4Cl_2 + 2HCl + 2ICl$$

The abnormal products obtained in these studies can be explained by assuming that the attacking reagent holds two chlorine atoms rigidly at such a distance that each attacks an adjacent carbon atom simultaneously. This is probably brought about by the existence of a transitory unstable cyclic intermediate. We have tentatively termed this phenomenon "Simultaneous ortho-dichlorination", and propose that the attacking reagent is probably I_2Cl_6. Experimental details and arguments for the mechanistic interpretation will be given.

Utilization of Limit Dextrins by the Animal Body

ANNE DE BOER DECKARD and R. C. CORLEY, Purdue University

Starch in nature appears to contain two types of polymers of glucose, the amyloses, with a linear type of molecule showing a blue color with iodine, and the amylopectins, with highly branched structures, which give a red color with iodine. *Beta* amylase, capable of splitting maltose from the non-aldehydic end of a chain, can complete the hydrolysis of amyloses, but can carry the splitting of the amylopectins apparently only to the points of branching, producing limit dextrins, residual substances of high molecular weight which give colors with iodine. *Alpha* amylase causes quick fragmentation of amyloses, amylopectins, or limit dextrins into reducing dextrins which yield no color with iodine.

Since *alpha* amylase is labile to acid whereas *beta* amylase is stable to acid at low temperatures, it is possible selectively to inactivate *alpha* amylase by treating a diastase preparation at 0°C. for 20 minutes in an acetate buffer solution at pH 3. Insoluble materials, including inactivated *alpha* amylase, were removed in a Sharples supercentrifuge after adjusting with NaOH to pH 4.6 and adding an equal quantity of ethyl alcohol. Increasing the alcohol content to 80% precipitated *beta* amylase which was filtered off and suspended in acetate buffer at pH 4.6-4.8. Overlaid with toluene, such a preparation was kept in the refrigerator until used. Several preparations of *beta* amylase were made in the laboratory, and one of high purity was obtained from a commercial source.

In connection with some studies of enzymatic splitting of starches, it has seemed of interest to investigate the utilization in the white rat of limit dextrins administered orally or parenterally. Limit dextrins in the alimentary tract would be expected to be readily digested, but those administered by another route might escape utilization.

Rice starch was selected as the source of limit dextrins because of its small granules and its relatively high yield of limit dextrins of higher molecular weight. The starch was defatted by stirring and refluxing it with 85% alkaline methyl alcohol for about 15 hours. Although washed with 95% methyl alcohol, the air dried defatted starch gave a distinct alkaline reaction when dissolved. From this there were prepared several ten liter batches of 2% sol with pH adjusted to 4.6 by addition of glacial acetic acid. The sols were incubated several days at 37°C. with *beta* amylase preparations. When little additional maltose was being produced, as shown by the Shaffer-Hartmann determination (3), additional portions of enzyme were added to insure that the hydrolysis by the *beta* amylase had gone to essential completion. For the Shaffer-Hartmann determination, 30 ml. of ethyl alcohol were added to 10 ml. of the digest to precipitate starch and dextrins. Twenty ml. of the filtrate was evaporated to about 5 ml., transferred to a 10 ml. volumetric flask and made up to volume with ethyl alcohol. Aliquots of this solution were treated according to the Shaffer-Hartmann procedure. The amount of reduction increased rapidly in a linear manner and suddenly leveled off. After digestion was discontinued, retrograded amylose and any flocculent precipitate present were filtered off and part of the dextrins was precipitated by adding an equal volume of 95% ethyl alcohol to the filtrate. After several reprecipitations and after grinding the product in a mortar with absolute alcohol and then with anhydrous ether, a light tan powder was obtained which was dried. This powder gave violet-red colors with iodine, was soluble in hot water, only slightly soluble in cold water, and was thought to have relatively high molecular weight. The filtrate was concentrated under vacuum and after further addition of alcohol a fraction of medium molecular weight was obtained. It was soluble in cold water and gave a red complex with iodine. Digests containing small amounts of *alpha* amylase yielded in addition small amounts of limit dextrins very soluble in water and which gave only a light red color with iodine. These were thought to have low molecular weight.

Young male white rats weighing 280-380 g. were deprived of food for 24 hours. Limit dextrins were administered in 5 ml. of water via stomach tube or subcutaneous injection. If the preparation of the limit dextrins was not sufficiently soluble, the dose was administered at hourly intervals in several more dilute portions. After 8 hours the livers were removed from the anesthetized animals and the glycogen determined (Table I) by the method of Good, Kramer, and Somogyi (1), as modified in this laboratory (2). Control experiments with rats fed starch, glucose, or maltose (Table II) and with rats sacrificed after a 36 hour fast were obtained.

TABLE I. Glycogen in the Liver of the White Rat After Administration of Limit Dextrins

Mol. Wt.	Mode of Administration	Dosage g/100 g. Body Wt	No. of Rats Used	% Glycogen
Low	Stomach tube	0.48	1	1.75
Medium	Stomach tube	0.57	2	1.15
Medium	Stomach tube	0.55	2	1.61
Medium	Subcutaneous	0.53	1	1.37
High	Stomach tube	0.47	1	2.05
High	Stomach tube	0.28	1	0.24

It appeared that glycogen was deposited in the liver of rats after the oral or subcutaneous administration of the limit dextrin preparations employed. Intestinal *alpha* amylase in the rat presumably continued the hydrolysis of limit dextrins. Van Genderen and Engel reported that a large quantity of *alpha* amylase was always found in the rat duodenum (5). The mode of introduction into the organism of the limit dextrins employed seemed to cause but little variation in the amount of

TABLE II. Glycogen in the Liver of the White Rat After Administration of Carbohydrates

Carbohydrate	Mode of Administration	Dosage g/100 g Body Wt	No of Rats Used	Glycogen Av. %
None			7	0.26
Glucose	Stomach tube	0.62	1	2.77
Maltose	Subcutaneous	0.60	1	1.94
Starch	Subcutaneous	0.59	3	1.33
Starch	Stomach tube	0.86	1	1.37
Limit Dextrin	Both methods	0.54	8	1.21

apparent liver glycogen deposited. The possible role of tissue, particularly liver, enzymes in promoting the utilization of injected polysaccharides is not clear. Formation of glycogen without any hydrolysis of the limit dextrins, or deposition of limit dextrins as such is conceivable. The fate of injected starch is analogously obscure.

Conclusion

After the oral or subcutaneous administration of several preparations of limit dextrins, glycogen or a similar polysaccharide was deposited in the livers of white rats.

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Acetylation with Isopropenyl Acetate[1]

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In 1936, Hardy (3) suggested the conversion of esters directly into the corresponding anilides by treatment with anilino magnesium bromide, which was readily obtained from any simple Grignard reagent and aniline. By replacement of the latter with other aromatic amines, substituted anilides also may be obtained. Koelsch and Tenenbaum, (6) in a similar manner, obtained *p*-toluides. Conversely, a solid derivative of the alcohol portion of a simple ester may be obtained by effecting an interchange reaction between 3, 5-dinitrobenzoic acid and the ester in the presence of concentrated sulfuric acid. (7) This method is applicable to a large number of simple esters but may not be used if either the alkyl group of the ester reacts with concentrated sulfuric acid. High-molecular-weight esters (→ 250) also fail to react.

For the identification of the acyl group in esters, Dermer and King (2) prepared the N-benzylamides according to a modified method by Buehler and Mackenzie. (1) The ester was refluxed with benzylamine in the presence of a small amount of ammonium chloride. The cooled mixture was washed with water, if necessary acidified with hydrochloric acid, and the solid amide filtered, dried, washed with ligroin, and recrystallized from aqueous acetone or ethyl alcohol. In 1940, Sah (8) obtained acid hydrazides by treating hydrazines with methyl and ethyl esters. Jacobs and Heidelberger (5) obtained a yield of seventy-eight to eighty-four percent of the theoretical amount of the chloroacetamide by treating a mixture of ethyl chloroacetate and chilled aqueous ammonia at a temperature maintained at 0-5°C. At higher temperatures there was more replacement of the chlorine and the yields were considerably lower. Henry, (4) in a similar way, prepared chloroacetamide by the treatment of methyl chloroacetate with cold aqueous ammonia.

All these processes, however, proceed well only when the esters used are of methyl and ethyl alcohols. Esters of higher alcohols should be subjected to a preliminary methanolysis. The purpose of the present investigation is to acetylate a number of amines with a special ester, isopropenyl acetate. By the use of this compound, results the formation of a by-product, acetone, which may be easily distilled from the reaction mixture. The isopropenyl acetate is also a low-boiling ester, which, if unused in the course of reaction, may be distilled simultaneously with the acetone. The reaction proceeds as follows:

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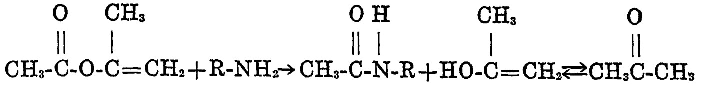
[1] An abstract of a thesis submitted to the faculty of Purdue University by H. H. Chen in partial fulfilment of the requirement for the degree of Master of Science.



$$CH_3\text{-}\overset{\overset{\displaystyle O}{\|}}{C}\text{-}O\text{-}\overset{\overset{\displaystyle CH_3}{|}}{C}=CH_2+R\text{-}NH_2\rightarrow CH_3\text{-}\overset{\overset{\displaystyle O}{\|}}{C}\text{-}\overset{\overset{\displaystyle H}{|}}{N}\text{-}R+HO\text{-}\overset{\overset{\displaystyle CH_3}{|}}{C}=CH_2\rightleftarrows CH_3\overset{\overset{\displaystyle O}{\|}}{C}\text{-}CH_3$$

In the course of the present investigation, several acetylations were conducted. The physical constants of the major acetylated products and those of the derivatives prepared from the by-product, acetone, agree very well with the data from the literature. The general procedures adopted are as follows:

An equi-mole mixture of the amine and the isopropenyl acetate is refluxed from one to four hours, depending on the different amines used. The acetone formed from the reaction and the isopropenyl acetate unused are distilled. The residue is a mixture of the acetyl derivative of the present amine and the unreacted amine. The acetyl derivative is isolated by one of the following processes:

(a) The residue from the distillation is poured into a large quantity of distilled water, then dilute hydrochloric acid is added with stirring. The precipitate is filtered, washed and dried.

(b) The residue from distillation is dissolved in acetone. This solution is added to a large quantity of dilute hydrochloric acid solution. The precipitate formed is washed with more dilute hydrochloric acid solution, then with water, filtered and dried.

(c) The residue from the distillation is dissolved in ether. This solution is extracted with several portions of dilute hydrochloric acid solution. The ether layer is separated, evaporated, and the residue is recrystallized from suitable solvents.

(d) The residue from the distillation is treated with a suitable solvent which will dissolve one of the two compounds, followed by either evaporation of the solvent or washing the residue with the same solvent. The residue obtained by either way is recrystallized from the same or another suitable solvent.

In the identification of the by-product, acetone, the following procedure is used:

A solution of 2,4-dinitrophenylhydrazine is prepared by adding to 0.4 g. of 2,4-dinitrophenylhydrazine, in a 25 ml. Erlenmeyer flask, 2 ml. of concentrated sulfuric acid. Water (3 ml.) is then added dropwise. To this warm solution is added 10 ml. of 95% ethanol.

A solution of the distillate in ethanol is prepared by dissolving 0.5 g. of the distillate in 20 ml. of 95% ethanol. The freshly prepared 2,4-dinitrophenylhydrazine solution is then added, and the resulting mixture is allowed to stand at room temperature. Crystallization of the 2,4-dinitrophenylhydrazone occurs within five to ten minutes. The 2,4-dinitrophenylhydrazone is filtered, dried, and its melting point determined.

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Centering of Rotating Microscope Stages

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A difficulty in using polarizing chemical and petrographic microscopes frequently encountered by students and by chemists inexperienced in microscopy is centering the circular rotating stage so that the center of rotation of the stage coincides with the optical axis of the microscope body tube and optical system. Accurate alignment of the center of rotation of the stage with the center of the observed field is necessary for measuring extinction angles, observing the behavior of interference figures, and many other purposes.

The scheme shown in figure 1 has been helpful in enabling students in chemical microscopy readily to align their microscopes. It was originally intended for those instruments having two adjusting screws below the stage facing the observer. The diagram may be conveniently displayed in the laboratory by reproduction on a sheet of white cardboard.

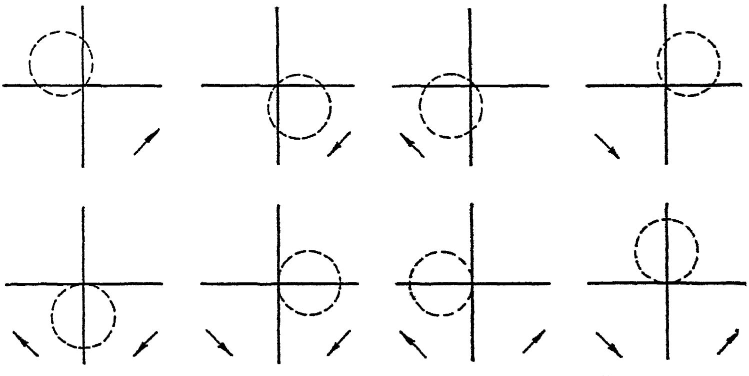

Figure 1. Procedure for Centering Rotating Microscope Stages.

In using the chart, the image of a small crystal or other object on a slide held on the stage is brought into coincidence with the junction of the cross-hairs of the ocular. The stage is then rotated and the circle described by the object relative to the junction of the cross-hairs is noted. This circle is represented on the chart by one of the dashed line circles if the stage is not correctly centered. The necessary adjustment is made by turning one or both thumbscrews according to the direction of the arrows. If the center of the circle described does not lie upon one of the cross-hairs, only one of the two conventional stage-centering screws is rotated as indicated in the upper half of figure 1. The position of the screw, left or right, corresponds to the observer being located below the illustration, i.e., facing the figure in the normal reader's position. If the center of the imaginary circle rests on one of the cross-hairs, both centering screws are adjusted as shown in the lower half of figure 1. The adjusting screws should be turned sufficiently to bring the center of the circle described by the object to the cross-hair junction. Usually, after each adjustment of the centering screws, the object is again brought into coincidence with the cross-hairs junction and the process outlined is repeated until the object remains at the cross-hairs junction on 360° rotation of the microscope stage.

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Objectives attached to the microscope body tube by an objective centering ring can be centered in an analogous manner. In the usual case where the adjusting screws on the objective centering ring are located in the two quadrants away from the observer, the chart required is similar to that in figure 1 except that the arrows are located in diagonally opposite quadrants; however, the arrows still point in the same direction. For example, in the upper extreme left situation of figure 1, the arrow now in the southeast quadrant would be transferred to the northwest quadrant; it would still point northeast.

Academic Training in Analytical Chemistry

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The extreme complexity of modern chemistry forces every chemist to become to some degree a narrow specialist, yet the dangers of overspecialization must be acknowledged by all. The academic training of every chemist should provide a firm basis of a thorough familiarity with all of the major divisions of chemistry, and to a lesser degree of related sciences, as a foundation for subsequent specialization. The need for a broad working familiarity with all phases of chemistry is particularly acute for the analytical chemist. Modern industry is demanding more analyses, it is demanding analyses more rapidly and often more precisely, and it is frequently demanding that the analytical results be adapted to automatic process control. To be able to respond to these demands, the analytical chemist should ideally be an expert in the diverse fields of organic chemistry and electronics, of inorganic chemistry and biochemistry, of instrumentation and others.

College and university offerings in analytical chemistry have been the subject of frequent critical reexamination within the past few years. Many possible changes have been suggested, some very sweeping and others minor, some of a long range nature and others of immediate possibility. The purpose of the present report is to record some viewpoints which have been expressed in extensive discussions at Indiana University between Professor L. L. Merritt and the present author.

The following features should be included, along with others, in a complete academic program for the professional analytical chemist:

1. a thorough grounding in the "classical" principles of analytical chemistry;
2. a comprehensive familiarity with chemical methods of analysis of important natural and manufactured materials;
3. a thorough survey of all of the major divisions of chemistry, including advanced course work in each;
4. a working familiarity with the type methods of instrumental analysis;
5. some class work and laboratory work in applied electronics;
6. some class work and laboratory work in the principles and methods of instrumentation, including automatic control devices;
7. specialization within some phase of analytical chemistry.

These seven considerations are commented upon in the following paragraphs, in which the numbers refer to the above listing.

1. It is felt that the first course in quantitative analysis should continue to emphasize the "classical" principles of the subject. The

basic principles of stoichiometric relationships, formation of precipitates and chemical equilibria are still the foundation stones of quantitative analysis. Any minor changes which can be made to make the subject more alive and more exciting to the student, however, are always of possible value. Many teachers now include some colorimetry in the first course. The use of a direct reading pH meter to obtain titration curve data is experimentally simple yet of value in making the theory of titrations seem more real. The author has found that the use of electron micrographs to illustrate precipitation phenomena adds much to student interest. Laboratory demonstration periods may be utilized from time to time to introduce, and even to exhibit in operation, some of the instruments and other modern developments within analytical chemistry. Students in the author's beginning quantitative analysis course have each semester exhibited keen interest in regularly scheduled guided tours through the laboratories which are used for advanced courses and for research in analytical chemistry. This latter is possible only in a school possessing a well-equipped graduate division, although modern instruments can be "shown" to any class by means of pictures in the wealth of literature made available by the manufacturers.

2. An advanced course in analytical chemistry, not including instrumental methods, is necessary to fulfill this requirement. Such a course is required of all graduate students at Indiana University. The analytical chemistry of each element is considered in turn. In addition this course provides opportunity for presentation of special topics, such as microanalytical methods, statistics in analytical chemistry, atomic weight determinations, new analytical reagents, and others.

3. There is much difference of opinion as to what portion of the graduate training of a chemist should be devoted to formal course work. Nevertheless, there can be little doubt that the analytical chemist in particular can benefit from extensive course work in all of the major branches of chemistry. All doctorate candidates at Indiana University are required to take at least two courses in each of four divisions.

4. This requirement can be met efficiently after the student has had at least some course work in the major fields of chemistry including physical chemistry. Both class work and laboratory work should be included. Although a senior level course in a large school can be satisfactory to fulfill this requirement, it generally necessitates a course for which graduate credit can be awarded. Emphasis should be placed upon the instruments available commercially, as well as upon the general applicability of each type method, the usual range of precision and accuracy, and other salient features.

5 and 6. It is felt that in many instances the electronics requirement can be met most efficiently by a course in electronics for chemists within the chemistry department. Such a course is currently available for graduate credit at Indiana University. This course at present includes brief introductions to instrumentation and to control devices. It is planned that this phase of the curriculum be expanded.

7. Specialization may be aided by special topics courses on an advanced level, by seminars and by research work.

In summary, some of the significant requirements which must be fulfilled by an adequate academic training for professional analytical chemistry have been enumerated, and comments have been made upon each with particular reference to the way in which these requirements are being fulfilled at Indiana University.

Beckmann Rearrangement of Oximes of Certain Quinolyl Ketones[1]

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Indiana University

Some early work has been done on the Beckmann rearrangement of oximes of quinolyl ketones. Matsumara (7) reported the rearrangement of 5-acetyl-8-hydroxyquinoline oxime to 5-acetamido-8-hydroxyquinoline and likewise 5-benzoyl-8-hydroxyquinoline was rearranged to the corresponding 5-benzamido compound. These rearrangements were carried out at 100° in a sealed tube containing a solution of the oxime in glacial acetic acid and acetic anhydride which had been saturated with hydrogen chloride. In a later publication (8), it was reported that thionyl chloride in ether caused the rearrangement of 5-benzoyl-8-hydroxyquinoline oxime to the anilide of 8-hydroxy-5-quinolinecarboxylic acid. Rearrangement in concentrated sulfuric acid was reported to also give the anilide. However, it was reported that the oxime of 5-acetyl-8-hydroxyquinoline was rearranged with thionyl chloride and sulfuric acid to give the same product as with acetic anhydride.

Howitz and Kopke (2) reported the isolation of two oximes of 8-benzoylquinoline, one melted at 121° and the other at 165°. The lower melting oxime was rearranged in ether by phosphorus pentachloride to give 8-benzamidoquinoline while the higher melting oxime gave 8-quinolinecarboxanilide. Matsumara (7, 8) did not mention the isolation of more than one form of the oxime of 5-benzoyl-8-hydroxyquinoline.

Recently, Huntress and Walter (3) have studied the rearrangement of the oximes of 2-benzoylpyridine. Two oximes were isolated; the lower melting one was rearranged in chloroform using thionyl chloride to give 2-benzamidopyridine while the higher melting form rearranged under the same conditions to 2-pyridinecarboxanilide. The authors found that both oximes gave the same product, α-picolinic acid and sulfanilic acid, when rearranged in concentrated sulfuric acid and the product subjected then to hydrolysis. They reported that the use of phosphorus pentachloride in ether did not give as good results as the thionyl chloride method. Huntress and Walter also reported that rearrangement of the benzenesulfonyl and p-toluenesulfonyl esters of the oximes occurred smoothly by merely refluxing solutions of the ester in solvents such as chloroform or benzene. In some cases, rearrangement occurred without heating.

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[1] Abstracted from portions of theses submitted to the Faculty of the Graduate School in partial fulfillment of the requirements for the degree, Master of Arts, in the Department of Chemistry, Indiana University, by J. D. G. (July, 1948) and J. C. G. (November, 1947).

The configuration of the oximes may be deduced from the knowledge that the group trans to the hydroxy group of the oxime moves to the nitrogen atom during rearrangement.

In the work reported in this paper, both the syn and anti-phenyl oximes of 6-benzoylquinoline were obtained since both benzoic acid and 6-quinolinecarboxylic acid were obtained by hydrolysis of the rearranged substances. The individual oximes were not isolated. The oxime of 6-acetyl-4-chloroquinaldine was of one configuration. Rearrangement of the oxime gave 6-acetamido-4-chloroquinaldine, therefore the oxime must have been the syn-methyl. The yield of 6-amino-4-chloroquinaldine though was rather low since there was extensive replacement of the chlorine atom by the hydroxy group during hydrolysis of the 6-acetamido compound. The melting point recorded for 6-acetamido-4-chloroquinoline ranges from 206° to 212° (4,5,1) which is in rather close agreement with the melting point of the substance isolated from the Beckman rearrangement. The melting point of the substance obtained by hydrolysis of the 6-acetamido-4-chloroquinaldine agrees with that of 6-amino-4-chloroquinaldine reported by Jacini (4) but not with the value, 145°, reported by Kermack (5). Phosphorus pentachloride in ether or in benzene gave better results than did the use of either thionyl chloride or sulfuric acid. The Beckmann rearrangement of the oxime of 6-acetyl-4-hydroxyquinaldine gave unworkable tarry materials.

The 6-acetyl-4-hydroxyquinaldine was prepared from methyl acetoacetate and p-aminoacetophenone by the well-known Conrad-Limpach method but boiling diphenyl ether was used as the medium for ring closure of the crotonate.

Experimental

p-Aminoacetophenone.—To a 2-liter three-necked flask fitted with a mechanical stirrer and a reflux condenser fitted with a trap to absorb hydrogen chloride, was added 270 g. (2 moles) of acetanilide, 530 ml. of carbon disulfide and 420 g. (5.35 moles) of acetyl chloride. The stirrer was started and about 5 g. portions of anhydrous aluminum chloride added through the third neck of the flask, stoppering it after each addition and waiting until the reaction subsided before more aluminum chloride was added; the total amount used was 934 g. (7 moles). The reaction mixture was refluxed for about thirty minutes, then the upper layer removed and the lower brown-colored layer was poured onto chipped ice. The cold mixture was stirred well, then the crude p-acetamidoacetophenone removed by filtration. The crude wet substance was refluxed for thirty minutes with a solution of 550 ml. of concentrated hydrochloric acid in 750 ml. of water, then the acid was just neutralized with sodium hydroxide, the aniline removed by steam distillation. After cooling in an ice bath, the p-aminoacetophenone was removed by filtration and purified by recrystallization from about three liters of boiling water after treatment with 5-10 g. of decolorizing charcoal. The yield of yellow crystalline material was 155.4 g. (58.2%), m.p. 103-105°. The melting point (2) recorded for p-aminoacetophenone is 104-106°.

Methyl β-(p-acetylanilino)-crotonate.—A 500 ml. round bottomed flask was fitted with a reflux condenser and a watertrap for use with a heavier than water liquid. A solution of 200 ml. of methylene dichloride, 65.7 g. (0.5 mole) of pure p-aminoacetophenone, 61.5 g. (0.53 mole) of methyl acetoacetate and three drops of 10% hydrochloric acid were refluxed until no more water was collected in the trap. The methylene dichloride was removed by distillation on a steam bath. After the residue cooled, the solid was triturated with 200 ml. of ligroin, filtered and washed twice with 100 ml. portions of ligroin. The yield of the crotonate, after drying in an air bath was 110 g. (95.3%), m. p. 80-83°. A portion of the crotonate was recrystallized twice from boiling ligroin (90-60° range), giving yellow-colored needles, but the melting point did not change.

Anal. Calc'd. for $C_{13}H_{15}NO_3$: N,6.06%. Found: N,6.49%.

6-Acetyl-4-hydroxyquinaldine.—A 1-liter three-necked flask was fitted with a mechanical stirrer, a separatory funnel and an exit tube 10 mm. in diameter with about a 6 in. vertical section connected to a water cooled condenser set downward for distillation. About 450 ml. of diphenyl ether was added to the flask then heated to boiling and a hot solution of 76 g. (0.34 mole) of crude methyl β-(p-acetylanilino)-crotonate in 125 ml. of diphenyl ether was added to the stirred boiling diphenyl ether at a rate so as not to allow the temperature to fall below 240°. After no more methyl alcohol distilled, the reaction mixture was allowed to cool, the solid was collected on a Buechner funnel, then washed with 150 ml. of a diphenyl ether-ligroin mixture (2:1) and finally with two 125 ml. portions of ligroin. The yield of crude 6-acetyl-4-hydroxyquinaldine was 56 g. (82%), m. p. 315-320 (dec.). The substance was obtained as light tan-colored crystals after recrystallization from 95% ethyl alcohol; m. p. 327-329°. The recovery of recrystallized material was 80%.

Anal. Calc'd. for $C_{12}H_{11}NO_2$: N,6.96%. Found: N,6.85%.

6-Acetyl-4-chloroquinaldine.—Crude, dry 6-acetyl-4-hydroxyquinaldine (35.3 g., 0.175 mole) was added portion-wise to 56.7 g. (0.37 mole) of phosphoryl trichloride and the reaction mixture was warmed a few minutes after all of the solid was in solution. The liquid mass was poured onto about 400 g. of ice, then the solution nearly neutralized with sodium hydroxide, the tarry material removed by filtration and the chlorocompound precipitated by neutralization of the clear filtrate. The solid was collected on a Buechner funnel, washed thoroughly with both water and a very dilute sodium bicarbonate solution, then dried at 70°. The yield of the crude substance was 36.7 g. (95.5%), m. p. 133-136°. The 6-acetyl-4-chloroquinaldine was purified by recrystallization from dilute ethyl alcohol (35%) and also from ligroin (b. p. 70-110°); the yield of light tan-colored crystals was 29.4 g. (77%); m. p. 137-137.5°.

Anal. Calc'd. for $C_{12}H_{10}ClNO$: Cl, 16.18%. Found: Cl, 16.33%.

6-Benzoylquinoline.—A 1-liter three-necked flask was fitted with a mechanical stirrer, thermometer, separatory funnel and a reflux condenser. The flask was supported in an oil bath. Added to the flask were 90 g. (0.45 mole) of p-aminobenzophenone, 130 ml. of glycerol, 42 g. of boric acid and 78 g. of arsenic pentoxide. The mixture was warmed to 115° and stirred until it became homogenous then 54 ml. of concentrated sulfuric acid was added at a rate so as to allow a gradual rise in temperature but not go above 130°. After all of the sulfuric acid had been added, the temperature was allowed to rise slowly to 138-140° where it was maintained for about seven hours. After cooling, the reaction mixture was poured onto ice, then the solution neutralized with concentrated ammonia water and the solid removed. The gummy mass was shaken with excess 10% sodium hydroxide and benzenesulfonyl chloride, the aqueous layer separated and the water-insoluble portion treated with excess dilute hydrochloric acid. The acid solution was filtered, then ice added to the filtrate and the solution made slightly alkaline to litmus by the addition of sodium hydroxide. The brown-colored solid was collected by filtration and after drying in the air, it weighed 62 g.; m. p. 33-39°. The crude 6-benzoylquinoline was purified by three recrystallizations from dilute (30%) ethyl alcohol. The substance was obtained as a white, flocculent type solid melting at 42-43°.

Anal. Calc'd for $C_{16}H_{11}NO$: N,6.01%. Found: N,6.07%.

6-Benzoylquinolinium Picrate.—The picrate was prepared by the addition of a saturated alcohol solution of picric acid to 0.5 g. of 6-benzoylquinoline in 10 ml. of 95% ethyl alcohol. The picrate was removed by filtration and recrystallized three times from absolute ethyl alcohol. It was a finely crystalline bright yellow solid melting at 212-214°.

Anal. Calc'd for$C_{22}H_{14}N_4O_8$: N, 12.12%. Found: N, 10.87, 11.00%.

6-Benzoylquinoline Oxime.—Five grams (0.02 mole) of 6-benzoylquinoline and 2.1 g. (0.03 mole) of hydroxylamine hydrochloride was added to a solution of 2 g. (0.05 mole) of sodium hydroxide in 125 ml. of absolute ethyl alcohol and the mixture refluxed for about fifteen minutes. Most of the alcohol was removed by distillation, then the mass poured into about 500 ml. of water containing 0.5-1.0 ml. of concentrated sulfuric acid. After standing for some time, the solid was collected on a Buechner funnel, washed and then dried at 70°. The yield of the crude oxime was 3.2 g. (61%), m. p. 174-190°. Recrystallization of one gram of crude 6-benzoylquinoline oxime from ethyl alcohol gave 0.7 g. of light yellow crystals, m. p. 204-206°.

Anal. Calc'd for $C_{16}H_{12}N_2O$: N,11.29%. Found: N,11.25%.

6-Acetyl-4-chloroquinaldine Oxime.—This oxime was prepared in a similar manner from 19.5 g. (0.49 mole) of 6-acetyl-4-chloroquinaldine. The yield of the crude oxime was 35.2 g. and possessed a very wide indefinite melting point range. To purify the oxime, 25.2 g. of the crude substance was refluxed with 800 ml. of absolute alcohol, the solution filtered and the oxime allowed to crystallize. After two recrystallizations, the yield was 14 g., m. p. 191-193°.

Anal. Calc'd. for $C_{12}H_{11}ClN_2O$: Cl, 15.12%. Found: Cl, 15.28%.

6-Acetyl-4-hydroxyquinaldine Oxime.—The substance was prepared from 12.2 g. (0.066 mole) of 6-acetyl-4-hydroxyquinaldine using the same ratio of reagents and conditions as in the preparation of 6-benzoylquinoline oxime. The yield of oxime was 12.6 g. (96%). The crude substance was dissolved in boiling ethylene glycol, the oxime allowed to separate, the solid washed with ethylene glycol, then boiled with two 50 ml. portions of ethyl alcohol. The recovery of the recrystallized oxime was 92%. The oxime was a light gray color and melted at 304-305°.

Anal. Calc'd for $C_{12}H_{12}N_2O_2$: N, 12.96. Found: N, 12.98%.

Beckmann Rearrangement of 6-Benzoylquinoline Oxime.—A 1-liter three-necked flask was equipped with a sealed stirrer and a reflux condenser with a calcium chloride attached. Eight grams (0.034 mole) of powdered 6-benzoylquinoline oxime and 500 ml. of anhydrous ether was added to the flask and the mixture stirred vigorously. Phosphorus pentachloride (14 g., 0.07 mole) was added in 12 portions over a period of about three hours while the temperature was maintained no higher than —10°. The temperature was allowed to rise to that of the room after an additional hour and the stirring was continued while the reaction mixture was refluxed for thirty minutes. Most of the ether was removed by distillation and the residue hydrolysed by the addition of ice. A portion of the acid was neutralized by sodium hydroxide, the solution filtered and the filtrate made slightly alkaline. The brown sticky solid which precipitated became hard and glossy after standing some time. The yield was 4 g. A small portion was recrystallized from absolute ethyl alcohol which yielded a white solid melting at 140-145°.

Anal. Calc'd. for $C_{16}H_{12}NO_2$: N, 11.29%. Found: N, 11.33%.

Three grams of the crude rearranged substance was refluxed for three hours with 30 ml. of 20% hydrochloric acid, then the solution made alkaline and the oil extracted with ether. The aqueous layer was warmed, then filtered and the cold filtrate acidified. The solid which separated was recrystallized from hot water giving a white crystalline acid which melted at 119-120°. A mixed melting point with benzoic acid showed no depression. The acid filtrate was made alkaline with concentrated ammonia water, then neutralized with acetic acid. After standing for a day, the solid was collected on a Buechner funnel and recrystallized from dilute ethyl alcohol. The substance melted at 285-288° (dec.). The melting point (9) recorded for 6-quinoline-carboxylic acid is 290-291°.

Beckmann Rearrangement of 6-Acetyl-4-chloroquinaldine Oxime.—Benzene (500 ml.) was added to a 1-liter three-necked flask containing 12.4 g. (0.052 mole) of powdered crude 6-acetyl-4-chloroquinaldine oxime. The flask was equipped with a mechanical stirrer and condenser, then immersed in a cooling bath and 22 g. (0.106 mole) of phosphorus pentachloride added in eight portions over a period of three hours while the mixture was stirred vigorously and the temperature was maintained at about 0°. After the reaction mixture warmed to room temperature, it was stirred for one hour then most of the benzene removed on a steam bath. Ice was added to the residue and the solution was boiled gently for a short time to remove the remainder of the benzene. The acidic solution was partially neutralized with sodium hydroxide, treated with 5 g. of norite and filtered through a Buechner funnel. After making the cold filtrate slightly alkaline with sodium hydroxide, a yield of 9.8 g. (79%) of a tan-colored solid was obtained, m. p. 176-180°. A small amount of the amide was purified by several recrystallizations from benzene; m. p. 205-206.5°.

Anal. Calc'd. for $C_{12}H_{11}ClN_2O$; N,11.94%. Found: N,12.34%.

A mixture of 3.5 g. of 6-acetamido-4-chloroquinaldine was refluxed for fifteen minutes with 10 ml. of 20% hydrochloric acid, then the solution filtered and made slightly alkaline. A yield of 2.6 g. of brown solid melting at 129-137° was obtained. The substance was extracted with hot benzene yielding a solid, which after recrystallization from benzene, melted at 169-169.5°.

Anal. Calc'd. for $C_{10}H_9ClN_2$: Cl,18.44%. Found: Cl,18.25%.

Summary

The Beckmann rearrangement on the oxime of 6-acetyl-4-chloroquinaldine resulted in the formation of 6-acetamido-4-chloroquinaldine. The oxime of 6-benzoylquinoline was a mixture of syn and anti forms and on rearrangement and hydrolysis of the mixed amides from the rearrangement, gave both benzoic acid and 6-quinoline-carboxylic acid. Several new quinoline compounds have been reported, namely, 6-acetyl-4-hydroxyquinaldine, 6-acetyl-4-chloroquinaldine, 6-benzoylquinoline and the oximes of these substances.

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Look It Up, Freshman

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We as chemistry instructors are faced with numerous problems when teaching the beginning chemistry student. Most of us realize the need for learning facts, laws, theories, symbols, equations, properties, etc. Also, we hope to get our students to think, to use these facts and others in their experience in solving their problems, whether they are chemical in nature or not. Often it is necessary to utilize other sources of information so, we attempt to familiarize our beginner with texts other than his own and some of the pertinent journals.

Last fall I decided to put more emphasis on the use of these other sources of chemical information. So, I suggested they examine some of the available general chemistry books when problems arose. The results were like ideas that we all have, sound good, but backfire. This was no exception.

Then as questions went unanswered I kept note of them and decided to check the texts myself. The results of examining thirty general chemistry texts, printed since 1939, are most surprising in terms of our problems. The first problem was a result of the laboratory manual, directions which read ". . . . use dilute alkaline permanganate solution." Of course, some students used ammonium hydroxide and a reaction took place before the other reagent was added. Why? Only one text of the thirty gave much information. Most of the rest stated that permanganate in acidic or basic solution was an oxidizing agent. Fourteen of these books did not have even potassium permanganate in the index. If one had wanted some information about this compound, it would have necessitated considerable searching.

Last year Dr. Brown of Purdue called attention to the inability of entering chemistry graduate students to give a method of hydrogen bromide production. We ran into this problem during a consideration of the halogens. Eight texts bypassed this completely, but some were very good. However, one might have picked the wrong ones.

The third unanswered problem was how one could precipitate lead chromate by adding lead ion to a dichromate solution. Most of the texts suggested this relationship $Cr_2O_7 \overset{\text{Base}}{\underset{\text{Acid}}{= \rightleftarrows}} CrO_4$. However, this is of little help to the freshman if he adds lead nitrate, which is acid, to the already acidic dichromate solution and still gets $PbCrO_4$. None of the texts were of much help on this one.

The fourth problem was an indicator problem, for in using phenolphthalein the students tried concentrated acids and bases and got some peculiar colors. Textbook survey reveals that phenolphthalein should become pink to red in the range 8.2±0.2—10.0±0.2. Fourteen of the examined books did not include this compound in their index.

The fifth question had to do with the methods of preparation and the properties of the phosphorus halides where phosphorus is tri or penta valent. Eleven texts did not mention them.

As a result of an attempt to answer these questions that might face any freshman it would seem that too many of our present general texts are not very satisfactory as reference books. I know the beginning book is not normally a reference, but for the beginner it should be, if he is to find help. Many of us like the shorter versions that are rather popular now, but he must have some other supplemental information if he is to succeed.

It was most interesting to note the variety of topics in some of the beginning books. For example, these: mayonnaise, van der Waals forces, horsepower, cyprian brass, American Chemical Society, getters, Mojave Desert, RDX, visual aids, etc., etc.

Perhaps we should examine more thoroughly the available references we have for our beginners. We should do our utmost to help them. Just turning them loose with chemistry texts is not sufficient.

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TABLE I. Textbook Summary

Dilute Permanganate sol'n.+NH_4OH	Preparation of HBr	Why Cr_2O_7=CrO_4=	Behavior of Phenolphthalein in strong acids and bases	Preparation and nature of PX_3 or $_5$
1. O	No	No Cr	Red in base	Nothing
2. O b	2 methods	Alkali	8.3-10 red	Both
3. NH_3R	1 method	Alkali	Red	Both
4. O b	No	None	Red	Nothing
5. O	No	Alkali	Pink	List only
6. O a	1	Alkali	Pink	None
7. ———	2	Alkali	———	Both
8. ———	No	No Cr	Red	None
9. ———	2	Alkali	Red	Both
10. O	2	Alkali	Pink	Both
11. NH_3R	1 ?	Alkali	Pink	PCl_3 & $_5$ only
12. ———	2	Alkali	———	Nothing
13. O.	1	Nothing	Red	Preparation
14. O.b.n.	2	Always get $PbCrO_4$	———	Preparation

TABLE I. Textbook Summary—Continued

	Dilute Permanganate sol'n.+NH_4OH	Preparation of HBr	Why Cr_2O_7=CrO_4=	Behavior of Phenolphthalein in strong acids and bases	Preparation and nature of PX_3 or $_5$
15.	O.b.	4	Alkali	$10^{-8.5}H^+$ Pink	Both
16.	O.b.n.	No	Alkali	Red	Nothing
17.	O.	No	Nothing	Red	Nothing
18.	NH_3 R	1	In equilibrium	Red	Both
19.	O	1	Alkali	Red	Both
20.	O	2	Nothing	Red	Nothing
21.	Complete Reaction	3	Alkali	———	Both
22.	O.	2	Alkali	———	Both
23.	O.	2	Alkali	———	Nothing
24.	O	No	Nothing	Red	Nothing
25.	NH_3 R	4	No Cr	———	Both
26.	———	No	No Cr	———	Nothing
27.	O.b.	1	Pb++ get $PbCrO_4$	Pink	Both
28.	O.b.	2	Nothing	Show Structure	Both
29.	O.b.	3	Alkali	Pink	Both
30.	O.b.	No	Alkali	———	PCl_5 only

O.—oxidizing agent
R.—reducing agent
a.—in acid
b.—in base
n.—in neutral

Preparation of Fluoboric Acid from Fluosilicic Acid and Boric Acid, and a Comparison of the Protective Value of Electrodeposited Lead from Fluosilicate and From Fluoborate Baths

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Abstract

Lead fluoborate electroplating baths give smoother and more impervious deposits than do lead fluosilicate baths. Unfortunately, fluoboric acid costs about 40 cents per pound compared to about 11 cents for fluosilicic. The high cost results from the present method of manufacture using boric acid and expensive hydrofluoric acid. The fluoborate baths are only used where the value of a superior quality of the deposit more than counterbalances the extra cost.

Boric acid will react with fluosilicic acid forming fluoboric acid and gelatinous silicic acid which is very difficult to filter. The loss of acid in the residue after filtration is the great objection to this method.

Method of Analysis

Knowing the quantity of fluosilicic acid in an experiment, the conversion to fluoboric acid was calculated by difference from the weight of sodium fluosilicate that was precipitated in 50 per cent alcohol.

Materials Used

A 27.4 per cent water solution of fluosilicic acid was available from a tank car of commercial acid as used by a lead refinery. This acid was made by the Davisson Chemical Company, Baltimore from the silicon tetrafluoride evolved by the reaction of sulfuric acid on phosphate rock in the manufacture of superphosphate fertilizer. The boric acid was the ordinary crystalline material supplied for laboratory use.

Experiments

The use of a solution of boric acid on the fluosilicic acid always gave such a bulky gelatinous mass of silicic acid that satisfactory filtration could not be accomplished. No greater recovery of the total acids in the filtrate than 55 per cent could be obtained by gravity filtration.

It is a well known fact that a solid reagent in a solution of the other material that is to be precipitated gives a more granular and therefore a more easily filtered precipitate. Therefore, all of the following experiments were with solid boric acid. In each case, the residue was allowed to drain by gravity. Then the residue was washed with one fourth as much water as the original volume of fluosilicic acid. Variations in temperature, time of reaction, stirring, etc., were all tried.

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An equivalent quantity of solid crystalline boric acid was allowed to stand quietly on the fluosilicic acid for varying periods of time. About 48 hours was needed for equilibrium at which time all but 16 per cent of the fluosilicic acid had been converted and 75 to 80 per cent of the total acids were recovered in the filtrate These results show that the rate of reaction on mere standing at room temperature is too slow and the recovery is not satisfactory. Of course, the recovery is dependent on the physical condition of the silicic acid residue which determines the efficiency of gravity filtration. The use of ten per cent excess of boric acid under these same conditions did not materially change either the time required or the per cent of conversion.

Apparently the solid pieces of boric acid must become coated with a rather impervious layer of silicic acid whereby the rate of reaction is reduced. If this is true, stirring of the reaction mass should speed up the reaction. With an equivalent quantity of solid boric acid and mechanical stirring at room temperature, an equilibrium was reached in two to three hours with the unconverted fluosilicic about 17 per cent and the total recovered acids about 88 per cent. With 10 per cent excess of solid boric acid, in stirred mixtures at room temperature, the equilibrium time, yield and recovery were not essentially changed. Even 100 per cent excess of boric acid raised the yield to only 10 per cent of unreacted fluosilicic acid in two hours but the total recovery was not changed. These results show that complete reaction is not a matter of quantity of boric acid used.

Equivalent weights of the boric acid and fluosilicic were used in the rest of the experiments. The unreacted fluosilicic acid was 40 per cent after 27 hours at 37°. The results were little better than 65°, although the speed of reaction was greater. Unreacted fluosilicic acid was 20 per cent and recovery was 81 per cent in 1.5 hours.

At 95°C, the equilibrium was reached in one hour with stirring, and the per cent of unchanged fluosilicic acid was 10 per cent, and the total recovery was about 80 per cent. This seems to be about the best results that could be obtained. However, the extra trouble of operating at 95°C more than counter-balances the time saved in reaching the equilibrium.

The use of boric acid, powdered to 40 mesh gave greater speed of reaction and as little as 10 per cent of unchanged fluosilicic acid, but the total recovery of acids was down to 70-75 per cent due to more bulky silicic acid.

A more dense form of the solid boric acid was prepared by previously heating the boric acid until it melted. Lumps of this dense form gave a rate of reaction that was very slow even at 95°C with stirring. After three hours the recovery reached 84 per cent but the unreacted fluosilicic acid was 30 per cent. This indicates that long continued reaction time might be satisfactory as recovery is improved by the change to dense boric oxide.

The fused boric acid, ground to 40 mesh, was also slow in reacting, and the conclusion is that previous fusing of the boric acid is not desirable.

Protective Value of Lead Electrodeposited from Fluosilicate and Fluoborate Baths.

The relative protective values of electrodeposited lead from the fluosilicate and the fluoborate baths showed the fluoborate much superior. Each bath contained five per cent of lead and seven per cent of free acid. All the acid ions in one were fluosilicate, and in the other fluoborate of the purity made by the method described here. The addition agent was 0.05 gm. glue and 0.1 gm. of goulac[2] per 100 ml. The lead deposits, 0.001 inch thick on iron, were tested with feroxal reagent for porosity. The deposit from fluosilicate showed 17 spots while only 6 spots showed on the fluoborate deposit in the same time

Summary

It is recommended that an equivalent weight of crystals of boric acid be stirred with the fluosilicic acid at 95°C. A 90 per cent change to fluoboric acid and an 80 per cent recovery of total acids is reached in one hour. At room temperature, about the same equilibrium is reached in three hours. Lead plated from a bath made with fluoboric acid showed only about a third as many pinholes as did a deposit from a fluosilicate bath.

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[2] This is the residue from sulfite paper manufacture.

Achievement in Chemistry under the Single Subject System

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Any innovation that promises more effective teaching of chemistry is of general interest to those seeking to improve the work of their classes and the single subject system, or concentration plan, has many teaching advantages claimed for it.

The opportunity for obtaining data to test these alleged advantages came with the appointment of the writer to Eureka College, where the single subject system had been adopted in 1939, after several years of preliminary testing. Previous to coming to Eureka College, the writer had offered instruction.in general chemistry under the conventional plan at Ball State Teachers College and at Indiana Central College at Indianapolis. Records in general chemistry from these schools are available and this paper presents a comparison of the achievements of the groups of students under the two plans.

The single subject system operates on the basis of four terms of eight and one half weeks instead of two semesters or three quarters of the usual school year. Under the concentration plan, a student registers for but one subject each term. Classes meet for three hours daily or a total of about 130 times during the term as compared with usual four hour course continuing through two semesters or three terms and meeting about 144 times during the entire course. In general chemistry, this means, under the concentration plan, two lectures or class hours each morning of the school week with one double-length laboratory period in the afternoon.

The records of students in general chemistry under the single subject plan are available from four classes at Eureka College; these are compared with the accomplishments of four similar classes under the conventional system. Measurement of achievement is taken from three sources, final grades in the course, from the number of superior ratings as well as from the number of unsatisfactory marks. This data has been criticised, perhaps rightly, as defective in that it represents the judgment of one individual, and hence is subjective, and being taken over a period of years, makes no allowance for changes of opinion with the passing of time.

It should be noted that the contents of the various courses were essentially identical under each system. The text used was McPherson, Henderson, Fernelius, and Mack, 1940 edition, and the manual designed to accompany it.

In analyzing the data, a special effort has been made to avoid the terminology and treatment of educational statistics and to present the material in a less technical manner. Where letter grades were given, these have been converted to grade-points with the usual values of four points for an "A", three points for a "B" and so on with the unsatisfactory rating (F) carrying a negative value of one.

Of the total number of students considered in this study, eighty-seven have received instruction under the single subject plan and an approximately like number under the conventional system. The work of four classes under each system are included.

The average passing grade of the concentration plan students was a 2.0 grade-point rating, a percentage equivalent of perhaps 72%. As might have been expected, the average final grade of the students receiving instruction under the conventional system, also fell within the C— range but a fraction of grade point below that of the concentration students, a numerical equivalent of perhaps 70%.

In the conventional classes 9.3% of the grades were unsatisfactory (F or WD) as compared with 12.5% for the concentration students. The number of "B" or better ratings among the concentration students was 35.3% with one small but exceptional class rising to almost 40% of the marks in the above-average group. The conventionally-taught students consistently received ratings of which 34.2% were above average.

Examination grades on the various types of questions—problems, factual, and explanatory—are less readily analyzed but the apparent tendency from a comparative series of examinations is toward a small but significant higher ratings for the concentration students.

Within the limits of this study, is concluded that: (A) Students in general chemistry are rated slightly higher on final grades in the course than the conventionally taught students.

(B) The number of students rated as better-than-average is greater under the concentration plan than under the conventional system.

(C) The number of unsatisfactory grades is smaller under the conventional plan than under the concentration system.

(D) The concentration plan appears to be more effective for the average to superior student and possibly less desirable for the below-average student.

(E) Additional data and study are needed to establish the relative values of the two systems of instruction.

Rapid Analysis of Dolomitic Limestones

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By use of the following procedure suggested by V. N. Tananaev[1] it is possible to analyze limestone for CO_2, CaO, and MgO in one laboratory period.

A .2 g sample is moistened with water and heated in a reflux condenser with 25 ml of .2 N HCl until gas evolution ceases. The sample is cooled and titrated with .2 N NaOH. After adding two or three drops of 3% hydrogen peroxide solution to the neutral mixture and making slightly alkaline with 6 N ammonia, the solution is treated with 25 ml of .2 N ammonium oxalate solution. The calcium oxalate is filtered, dissolved and titrated with potassium permanganate. The per cent MgO is computed from the difference between the CO_2 and CaO equivalents.

As shown in Table I our results averaged .3% high for CO_2 while the calcium compared favorably with standard procedures.[2]

Sample	CO_2 (det)	CO_2 (given)	CaO (det)	CaO (given)
1	42.50	42.33	33.46	33.55
2	43.57	43.22	34.90	34.92
3	41.83	41.35	47.76	47.80
4	40.31	39.87	44.50	44.57
5	41.44	41.27	44.75	45.91

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[1] V. N. TANANAEV. 1948. Zavodskaya Lab, **14**, 1131-2.

[2] I wish to thank Mr. W. R. Graves who checked the accuracy of this method.

The Addition of Nitrogen Tetroxide to Ketene

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Introduction

Nitrogen tetroxide will react with a carbon-carbon double bond to produce various addition products, mostly dinitro and nitro-nitrite derivatives.(3) Nitryl chloride will react with ketene to produce small amounts of nitro-acetyl chloride. (4) Nitrosyl chloride and ketene produce chloroacetyl chloride. (2) Bolstad (1) reports that ketene and nitrogen dioxide react in the gaseous phase to give a liquid product which has not been identified. He found, moreover, that diketene and liquid nitrogen tetroxide react with explosive violence.

In view of these facts, this investigation undertook to determine if an addition type of reaction would take place between ketene and nitrogen tetroxide. Such an addition product, upon hydrolysis or alcoholysis, should produce nitroacetic acid or an ester of nitroacetic acid.

In an attempt to prepare methyl nitroacetate directly and without the isolation of any intermediate product, methyl alcohol was added directly to the reaction product, the solvent was removed by evaporation, and the product distilled. Such procedures gave products which were unstable to distillation, exploding or fuming off at bath temperatures of 45 to 50°C.

The use of potassium hydroxide in place of methyl alcohol in the above procedure was investigated. If the nitrogen tetroxide-ketene reaction goes as expected, this should produce the dipotassium salt of nitroacetic acid. No evidence of the presence of this salt could be detected.

Since the properties of the nitrogen tetroxide-ketene product suggested those of nitroform, attempts were made to isolate this substance, but no positive results were obtained In like manner, no nitromethane could be isolated.

The use of ether at —60°C. as a reaction solvent was tried, but gave a product which was unstable at room temperature.

Isolation of the product produced by the reaction of ketene and nitrogen tetroxide was accomplished. It proved to be spontaneously inflammable when dried.

The use of a less active ketene, diphenylketene, was investigated briefly. It was found that the product of this reaction was a yellow brown oil stable at room temperature, but which decomposed on heating to liberate oxides of nitrogen. An unidentified organic residue remained.

Experimental

Attempted Preparation of Methyl Nitroacetate. Twenty-seven g. of nitrogen tetroxide was dissolved in 300 ml. of carbon tetrachloride and cooled to 0°C. Eight ml. of liquid ketene was passed into the reaction chamber by the use of nitrogen as a carrier gas. During the reaction a slow stream of oxygen was passed through the reaction mixture to prevent the reduction of nitrogen tetroxide to nitrogen sesquioxide. After the reaction was complete, 25 ml. of methyl alcohol was added, the solution was allowed to come to room temperature, transferred to a distillation flask, and the solvent removed under reduced pressure. The residue, about 5 ml. of a yellow brown oil, exploded when the bath temperature reached 45°C.

Ether as a Solvent. The procedure used here was similar to that used in the previous experiment except that the solvent used was ether and the reaction was carried out at —60°C. When the reaction was complete no methyl alcohol was added, but the reaction mixture was allowed to warm to room temperature. The solvent was then removed by distillation and the residue amounted to about 10 ml. of a yellow oil. Upon warming to room temperature, the product decomposed rapidly with the evolution of oxides of nitrogen and considerable heat.

Attempted Preparation of the Dipotassium Salt of Nitroacetic Acid. A sample of the reaction product prepared in the manner described in the preceding experiment was dissolved in 100 ml. of water and made basic with 50 per cent potassium hydroxide solution. The resulting red solution was then concentrated by boiling until a solid began to separate out. After cooling, the solid was collected but proved to be an inorganic derivative.

Attempted Identification of Nitroform as the Reaction Product. Another sample of the reaction product obtained in ether solvent was dissolved in ether and a few drops of pyridine was added. No crystalline solid corresponding to the pyridine salt of nitroform was obtained.

Diphenylketene and Nitrogen Tetroxide. A solution of 8 g. of diphenylketene in 50 ml. of ether was added dropwise to a solution of 4 ml. of liquid nitrogen tetroxide in 100 ml. of ether cooled to 0°C. During the addition a slow stream of oxygen was passed through the reaction mixture. No visible reaction took place but removal of the solvent left about 4 ml. of a yellow brown oil. This product appeared to be stable at room temperature but decomposed on heating to give oxides of nitrogen. Analysis of the residue gave no conclusive results.

Summary

The reaction between nitrogen tetroxide and ketene produces a solid which is spontaneously inflammable when freed from the reaction solvent. Its structure has not been determined.

No solid separates out when diphenylketene is added to a solution of Nitrogen tetroxide, but a liquid residue apparently stable at room tem-

perature is left upon removal of the solvent. The structure of this product has not been determined.

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Dehydrogenations by means of Sulfur: Adaptation as an Experiment for General Organic Chemistry Course

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The literature contains numerous references to reactions between sulfur and pure individual organic compounds. While the action of sulfur on organic compounds is frequently thought of merely as a means for preparing hydrogen sulfide, the reaction may serve for dehydrogenation, ring closure, addition of sulfur and other purposes.

Although the element sulfur has for many decades been used for removing hydrogen from compounds, this property has not received much attention in the general organic chemistry course. Most introductory text books ignore sulfur dehydrogenation, or, at most, make only brief reference to the subject; probably none of the laboratory manuals include any experiments on this procedure. Over the years a fairly large variety of dehydrogenations has been reported. By heating a mixture of sulfur and diphenyl methane, Ziegler obtained the olefin tetraphenyl ethylene. Using a sealed tube, Aronstein obtained stilbene (or 1, 2-diphenylethylene) from sulfur and toluene. Hydroaromatic compounds such as tetrahydronaphthalene can be made to liberate their surplus hydrogen by heating with sulfur at 180°-250°. Various alkylated tetrahydronaphthalenes yield similar results. In the study of terpenes, sulfur dehydrogenations have played an important part. Other types of compounds which have been dehydrogenated by this process include certain acids, as abietic acid; aromatic ethers, and even certain sulfur compounds, such as diphenyl sulfide and cyclohexanthiol.

Some of these dehydrogenations could be adapted to form interesting experiments in a general organic chemistry course. A single example will be considered.—A rather intriguing reaction is one investigated by von Mantz and Graebe about 50 years ago. By heating a mixture of sulfur and fluorene at 350° these astonished researchers obtained hydrogen sulfide and a red solid. Repeated attempts to purify their product failed to remove the color from the reddish needle-like crystals, whose formula indicated the unsaturated compound, bis diphenylene-ethylene.

This procedure can readily be carried out by a student by heating a mixture of 5 g. fluorene and 1½ g. sulfur to gentle boiling for ¾ hour, during which time hydrogen sulfide is evolved. The red compound may then be isolated by extracting the black residue with several portions of hot benzene. After treating the solution with charcoal the product can be separated as a reddish orange powder When this powder is recrystallized from chloroform, microscopic crystals are obtained.

Although this dehydrogenation involves only simple procedures the experiment is of interest since a colorless hydrocarbon is transformed into a colored compound merely by removing hydrogen. Other dehydrogenations could be selected to provide any desired degree of difficulty.

Modification of the Orthotolidine Method for Determining Small Amounts of Iodine

W. E. THRUN, Valparaiso University

The Lange-Ward (2) method has been modified to increase reliability and sensitivity. A buffer is used which insures the optimum pH of 4.0 for the color reaction. The method is not suitable for use with a colorimeter because of constant color change. Its sensitivity is about one tenth that of the starch Iodine-iodide reagent of Gross et al. (1).

Reagents

A .6% alcoholic (95%) solution of orthotolidine or an aqueous solution prepared by dissolving one gram of ortholidine in 100 ml. water and adding 6.5 ml. of glacial acetic acid.

A buffer solution. Dissolve 3.0 grams sodium acetate Trihydrate, 7.7 mls. of glacial acetic acid in 10 mls. of water.

A 3% solution of hydrogen peroxide.

Standard solutions of potassium iodide containing 0.2, 0.4, 0.6, 0.8 and 1 to 10 p.p.m. iodine. In the upper range intervals of 0.5 or less p.p.m. iodine may be desirable.

15 x 25 mm matched specimen or test tubes.

Procedure

Five ml. of the sample and of standard solutions are pipetted into the tubes. Four drops of the buffer solution and 0.2 ml. orthotolidine solution are added and mixed. Then 3 ml. of hydrogen peroxide solution are added and mixed again. Colors are compared 10 to 15 minutes later.

Discussion

The 0.2 p.p m. iodine solution does not give a distinct color until it is 10 minutes old.

The aqueous solutions of orthotolidine do not become brownish and gelatinous as soon as the alcohol with the test solutions. Both reagent solutions turn somewhat brownish upon standing, but this does not affect the comparative results. In a range of 0.2 to 1.0 p.p.m. it is possible to differentiate between solutions of .2 p.p.m. differences and in the range of 1 to 5 p. p. m. between differences of 0.5 p. p. m.

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ENTOMOLOGY

Chairman: E. KINTNER, Manchester College

G. Gould, Purdue University, was elected chairman for 1950.

ABSTRACTS

Biology of *Gibbium psylloides* (Czemp.) FRANK E. BOHMAN, West Hartford, Connecticut.—*Gibbium psylloides* was reared both under room and constant temperature conditions on the following foods: paprika, wheat kernels, raisins, corn kernels, cocoa, dried white bread, epsom salts, wheat flour, dried milk, chili powder, balsa wood, corn meal, and cloves. The insect was unable to complete its development on cloves, balsa wood and epsom salts.

Eggs hatched on an average of 5.8 days at room temperature and in 7.6 at constant temperatures (80.9°F.). There are three larval instars. On the average 40.5 days were required for larval development at room temperatures and 37.7 at constant temperature The pupal period averaged 37 days at room temperatures and 21.6 at constant temperatures. The adults lived on an average of 140 days under room conditions and 84.9 in the constant temperature cabinent. On an average each female produced 12.98 eggs under room conditions and 7.07 under cabinent conditions. The average life span under room conditions was 223.4 and 151.8 days at constant temperature.

The possibilities of ultrasonics in insect control, HOWARD O. DEAY, Purdue University.—Ultrasonics has been used experimentally to kill various species of insects. Indications are that it may have some practical applications in the control of stored grain and structural pests.

Some problems encountered in nematocide screening. HOWARD W. SMITH, Purdue University.—The availability of test organisms and their suitability for certain screening procedures are often limiting factors in nematocide testing—test procedures are often designed to make use of specific nematodes. There is a need for laboratory scale test methods.

Laboratory Tests on the Toxicity of Technical DDT, DDT Isomers and Analogues, and DDD[1]

PHILIP W. BERG, Purdue University

Object of Investigation

Technical DDT and some of its more common isomers and analogues were to be compared by laboratory tests as to toxicity to four common species of insects, the pomace fly, *Drosophila melanogaster* Meig., the acrobat ant, *Crematogaster lineolata* Say, the spotted ladybird beetle, *Megilla fuscilabris* Muls., and the striped blister beetle, *Epicauta vittata* Fab.

Chemicals

The chemicals used, together with information as to purity, were generously supplied by the Geigy Company, Inc. of New York and E. I. Du Pont de Nemours Company, Inc. of Wilmington, Delaware. Most of the chemicals were supplied from laboratory stocks and were not commercially available. The ten chemicals used were:

1. DTolT Geigy. Ditolyltrichloroethane, about 90 per cent p,p' isomer of the methyl analogue of DDT.

2. DBrDT Geigy. Dibromodiphenyltrichloroethane, 90 to 95 per cent bromine analogue of DDT.

3. DFDT Du Pont. Technical grade fluorine analogue of DDT. Bradlow and VanderWerf (1) found a similar material to be composed of practically all p,p' isomer.

4. DMDT Geigy. Dimethoxydiphenyltrichloroethane, 99 to 100 per cent methoxy analogue of DDT.

5. DMDT Du Pont. Dimethoxydiphenyltrichloroethane, about 99 per cent p,p' isomer of methoxy analogue of DDT.

6. DDT. Geigy's technical grade dichlorodiphenyltrichloroethane, 90 degrees centigrade set point. Analyses by Gunther (7) and Haller *et al* (8) showed about 70 per cent of p,p' isomer, about 18 per cent of o,p' isomer, and about six per cent o,o' isomer DDT to be the major constituents, with a variety of minor constituents also present.

7. o,p'-DDT Geigy. 1-trichloro-2- (o.chlorophenyl) -2- (p.'chlorophenyl)ethane, 90 to 95 per cent pure.

8. p,p'-DDT Geigy. 1-trichloro-2-bis(p.chlorophenyl)ethane, 99 to 100 per cent pure.

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[1] This paper is based on a Master's thesis submitted at Purdue University in August, 1948.

9. p,p'-DDT Du Pont. 1-trichloro-2-bis(p.chlorophenyl)ethane, about 97 per cent pure.

10. DDD Geigy. Dichlorodiphenyldichloroethane, 99 to 100 per cent pure.

The DFDT was a viscous, amber fluid at room temperature; all the other chemicals were white, crystalline powders.

Preparation of Deposits of the Chemicals

It was desired that a thin, uniform deposit be obtained for exposing the insects.

In preliminary experiments when acetone solutions of the chemicals were allowed to dry on glass surfaces, even high concentrations of material did not give uniform deposits. More satisfactory deposits were obtained when acetone solutions were used to impregnate small rectangles of paper.

Acetone solutions were prepared to contain 2.5 grams of chemical per 100 milliliters of solution; and one milliliter portions were pipetted out onto 1½ x 4 inch rectangles of an absorbent, heavy, white paper. The paper slips were supported on solvent-washed glass plates and air dried for 12 to 16 hours before use.

A series of weighings was carried out and it was found that 21 to 24 milligrams of material was retained in each slip of paper for an average of 3.5 to 4.0 milligrams per square inch.

Because of an anticipated higher sensitivity of the acrobat ant to the chemicals used, half milliliter portions of the solutions were used in preparing papers for those tests.

The Test Insects

The pomace flies used were bred from a culture of Swedish B strain maintained in the Department of Biological Sciences of Purdue University. They were cultured at room temperature in wide-mouth, four ounce, glass bottles containing a medium prepared from cornmeal, agar, molasses, and water, with a small amount of mold-inhibiting chemical added. A few drops of yeast suspension were added to each bottle 12 to 24 hours before flies were to be introduced.

The acrobat ants were secured by field collection from colonies in a wooded area near Lafayette. An inspirator bottle was used.

The spotted ladybird beetles were collected with the aid of an inspirator bottle from sweet corn in the vicinity of Lafayette.

The striped blister beetles were collected from an infestation on potatoes at a Purdue experimental farm.

Manner of Testing

Four ounce, wide-mouth bottles served as test chambers for each of the four species. The dried, impregnated papers were bent and inserted into these bottles; they were stiff enough to maintain their positions near the tops of the bottles.

For all four species five replications of tests were made with each replication including the ten chemically impregnated papers, one control with acetone treated paper, and one control with untreated paper.

In preparing the pomace fly tests, flies were used one week after emergence began. Carbon dioxide was used to immobilize the flies in the culture bottles. Then flies from four or five bottles were shaken out into a shallow pan loosely covered with a glass plate and the flies were mixed by shaking them about. Carbon dioxide anaesthesia was maintained in the pan as the flies were counted out into lots of 50 each. A small camel's hair brush was convenient for counting the flies and sweeping them onto small paper slips by means of which they were easily transferred into the test bottles. The test bottles were actually culture bottles complete with medium, seeded with yeast, and fitted with cellucotton plugs. The bottles were placed on their sides so that the flies rested on the clean glass wall above the medium while they recovered from the anaesthesia. This prevented them from resting on the impregnated paper and from becoming mired in the medium (which liquefied somewhat) while recovering from the anaesthetic.

The acrobat ants used in any one replication were all from the same nest. They were counted out in lots of 20 each for the tests and were handled under carbon dioxide anaesthesia in about the same way as the pomace flies. A weak solution of sugar was supplied in each test bottle in a small vial loosely stoppered with cotton. The tests were closed with several layers of cheesecloth and stored on their sides.

The spotted ladybird beetles were also handled and counted with the aid of carbon dioxide anaesthesia. Ten beetles were used per test; plain water was supplied in each test bottle in a loosely stoppered vial; and the tests were closed with cheesecloth and stored on their sides.

The striped blister beetles were handled, counted into lots of ten, and introduced into the test bottles without the use of anaesthesia. In each test chamber a water vial was supplied and, in deference to the voracious appetite of the beetles, two small, fresh cucumber leaves were supplied. The tests were stored on their sides.

Records

Throughout these experiments no less than a complete replication (ten chemical tests and two controls) was set up at any one time. In order that records could be taken conveniently every 12 hours it was convenient to start the tests either in the morning or evening.

Records taken were of the numbers of insects "down", "dead", or "alive". "Dead" was taken as meaning completely devoid of reaction to stimuli or of any signs of life. "Down" was taken to mean incapable of locomotion or of the righting reaction. "Alive" was taken to mean capable of locomotion and the righting reaction even though, perhaps, displaying toxic symptoms such as incoordination.

In no case in any of the tests was there any indication of recovery by insects recorded as "down".

Observations of the surplus insects remaining after tests were set up showed no mortality due to the anaesthetic.

Results

For evaluating the results of these experiments the records for the last readings before the control insects started to die off rapidly were used. For the pomace fly that is the 60 hour reading; for the acrobat ant, the 36 hour reading; for the spotted ladybird beetle, the 84 hour reading; and for the striped blister beetle, the 36 hour reading.

An analysis of variance was worked out on these records.

Table I summarises the data and presents the required differences for significance at odds of 19 to one.

Table I. Mean Survival of Pomace Fly, Acrobat Ant, Spotted Lady Bird Beetle, and Striped Blister Beetle; and Differences Required for Significance at Odds of 19 to 1.

Chemical	Purity	Pomace fly	Acrobat Ant	Lady Bird Beetle	Striped Blister Beetle
DTolT Geigy	90% p,p'	45.0	16.0	1.0	9.4
DBrDT Geigy	90-95%	36.2	17.2	5.6	5.8
DFDT Du Pont	Tech.	0.0	0.0	0.0	2.4
DMDT Geigy	99-100%	39.8	17.6	4.6	7.6
DMDT Du Pont	97% p,p'	45.0	17.3	4.6	4.8
DDT	Tech.	2.2	3.2	2.0	3.2
o,p'-DDT Geigy	90-95%	45.6	15.8	6.4	8.4
p,p'-DDT Geigy	99-100%	4.6	2.3	4.2	2.4
p,p'-DDT Du Pont	97%	5.6	6.6	3.0	2.6
DDD Geigy	99-100%	39.8	16.8	6.4	7.8
Acetone (control)	.....	46.2	19.0	8.2	8.8
Untreated (control)	.....	48.2	17.8	8.4	8.2
Difference required at odds of 19 to 1		15.54	5.30	2.51	2.42

In connection with the information given in Table I it should be noted that with the pomace fly DFDT Du Pont produced complete mortality in four replicates at 12 hours and at 24 hours in one replicate; and DDT produced complete mortality in one replicate at 24 hours, in one replicate at 36 hours, and in one replicate at 48 hours. With the acrobat ant DFDT Du Pont produced complete mortality in 12 hours in two replicates, and in 24 hours in two replicates. With the spotted ladybird beetle DFDT Du Pont produced complete mortality in one replicate at 36 hours, in one replicate at 48 hours, and in three replicates at 60 hours.

A fumigant action by DFDT Du Pont was suspected and was subsequently verified in a supplementary experiment with the pomace flies. It should be noted, however, that cheese cloth covers were used on the ants and ladybird beetles and ventilation of these tests would be expected to be adequate.

From Table I it is apparent that the results obtained with one species in general parallel those obtained with the others. For all four species four materials, DFDT Du Pont, DDT, p,p'-DDT Geigy, and p,p'-DDT Du Pont, were significantly effective. If the rapidity of action is considered, DFDT Du Pont would be indicated to be first and DDT would be second.

Although Table I is self-explanatory, one should point out a few further items: (1) Ordinary technical DDT compared remarkably well with the more highly refined p,p'-DDT samples. (2) The sample of methyl analogue was significantly effective only against the spotted ladybird beetle. (3) The samples of methoxy analogue and of bromine analogue were definitely inferior to DDT in insecticidal efficiency. (4) The samples of DDD and o,p'-DDT were practically ineffective.

Comparative Data in the Literature

The author attempted to examine all literature reports having bearing on comparisons among the isomers and analogues of DDT. Of this literature only a rather small fraction is particularly pertinent.

One of the species used here has been previously used in similar tests. In 1945 Morrison (12) reported on the use of pomace flies for exposure to deposits of chemicals impregnated into paper. In 1947 Proverbs and Morrison (16) reported on the use of this technique in testing eighteen chemicals including technical DDT, fluorine, bromine, and methyl analogues, and DDD, among others. They found the halogen analogues to be, in order of decreasing toxicity, fluorine, chlorine, bromine, and iodine. All analogues except the fluorine analogue were less toxic than DDT. Further, the fluorine analogue was found to be somewhat volatile and less persistent but about nine times as effective as the technical DDT at twenty hours exposure.

In 1946 Kirkwood and Dacey (9) reported on tests of three fluorine analogues against the pomace fly. The p,p' analogue was the most effective, but only about two fifths as effective as DDT.

In 1947 Metcalf and Gunther (13) reported p,p'-DDT ten times as effective as the methyl analogue and a hundred times as effective as the promine analogue against the pomace fly.

Considerable comparative work has been done on houseflies and mosquitoes. In 1943 Prill *et al* (14) ran tests on houseflies by means of the Peet-Grady technique. They found the ethoxy, and methoxy analogues (among others) to be inferior to DDT. Others of their tests rated the methoxy analogue equal to DDT against mosquito larvae. In 1946 Gersdorf (6) compared o,p'- and p,p'-DDT against houseflies and found the p,p' isomer forty-four times as effective at the ten per cent L. D. Neither gave fast knockdown.

In 1946 Prill *et al* (15) reported on a three year investigation of the comparative toxicities of thirty-two chemical relatives of DDT as tested against *Culex quinquefasciatus* and the housefly. They found the methoxy analogue gave a more rapid knockdown but less total toxicity than DDT. From the results of these and other investigations the authors concluded that substitution of radicals larger spatially than methoxy or ethoxy radicals into the p,p' positions, and any variation from the p,p' positions greatly reduced toxicity.

In 1947 Fay *et al* (5) tested several organic compounds for residual action against houseflies and mosquitoes over a twenty-six week period. DDT proved superior to DDD in these tests.

Comparative work has also been done on lice and bedbugs. In 1946 Busvine (2) summarized the results of tests of forty-one analogues of DDT against bedbugs and human lice with the general conclusion that DDT and the chemicals closest to it in chemical structure were the most effective. In another article Busvine (3) rated DDT superior to DDD and both superior to the fluorine analogue when used against the same two species.

In 1946 Cristol *et al* (4) reported the o,p' isomer of DDT ineffective and the o,o' isomer only slightly effective against lice. In 1947 Riemschneider (17) reported making some fluorine analogues of DDT and claimed one of them was the most effective insecticide yet made. Against lice one per cent of this fluorine analogue was as effective as ten per cent DDT.

In 1944 Martin and Wain (11) reported on tests of various DDT analogues as contact poisons against several species. They concluded that the fluorine analogue had the highest insecticidal effectiveness, that technical DDT was of intermediate effectiveness, that the bromine and iodine analogues were of low effectiveness, and that organic-substituent analogues were still less effective.

Knipling in 1947 (10) suggested that although the methoxy analogue and DDD were generally less effective than DDT as insecticides, they had promise of being useful because of a lesser toxicity to warm blooded animals.

Conclusion

The results of this work appear to be largely in accord with results obtained by others with the same and other species of insects. Technical DDT, p,p'-DDT, and the fluorine analogue of DDT are shown to be more effective against the pomace fly, the acrobat ant, the spotted ladybird beetle, and the striped blister beetle, than are others of the more common isomers and analogues.

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Legume Pollination Problems[1]

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During the past two decades there has been a gradual and consistent decline in the quantity and quality of the legume seed produced in the relative humid areas lying east of the Mississippi River. Legume seed production in Indiana has followed a similar trend, the yields during the last eight years having reached a very low level as shown in table I.

TABLE I. Acreages and yields of legume seed grown in Indiana.[2]

Year	Red Clover		Alfalfa		Alsike		Sweet Clover		Lespedeza	
	acres	bu.	acres	bu.	acres	bu.	acres	bu.	acres	bu.
1941	244000	.90	16800	.85	6000	1.20	5900	2.80	28000	3.83
1942	134000	.75	2000	.85	3000	1.10	6400	1.90	14800	3.17
1943	194000	.70	1500	.75	1800	1.20	4500	2.40	27000	2.58
1944	360000	.70	27000	.75	4000	.90	6800	1.50	33000	5.50
1945	180000	.70	8600	.70	3500	1.00	5000	2.00	18000	3.17
1946	420000	.70	8200	.50	5000	.90	4500	2.00	34000	3.38
1947	139000	.65	5000	.75	2000	1.00	3500	3.00	24000	4.58
1948	291000	.65	2000	.80	3000	1.00	1600	1.50	36000	4.41
Av. 1941—48	242250	.72	8887	.74	3537	1.03	4775	2.14	26850	3.51
Av. 1931—40	203100	1.01	7400	.96			4700	2.20	30000	2.13

There are many factors responsible for this situation. These include plant diseases, cultural practices, destructive insects, and lack of adequate pollination. Of the legumes grown for seed in Indiana, alfalfa and red clover offer the most serious problems in pollination.

In the past legume seed producers have depended on native bees to carry the burden of pollinating the legume flowers. The trend in recent years toward more intensive farming has resulted in the reduction of the types of areas in which native bees nested. Removal of heavy growth along fence rows, intensive pasturing of wooded areas and clearing of undergrowth, ditching and straightening of streams and rivers, and draining of low swampy areas have all contributed to a changing ecology and the reduction of the native bee populations. Diseases of native bees, particularly the bumblebee, may also have contributed to this reduction. Not so many years ago it was a common occurrence to plow up bumblebee nests when fall plowing, an occurrence which is rare today. Unless care is used in applying the many new chemicals for weed control, further depletion of our native beneficial insects may occur through the destruction of such flowering plants as dandelions, wild asters, goldenrod, and smartweed, which are essential pollen and nectar sources for maintaining and increasing these insects. Since farming practices and other ecological factors have resulted in a diminishing native bee population over large areas of Indiana, interest has been focused on the use of the honeybee for the pollination of alfalfa and red clover.

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[1] Contribution from the Department of Entomology, Purdue University, Journal Paper No. 438.

[2] Justin *et al,* 1946 and 1948.

Beard and Dunham (1) have shown that with an optimum stand, maximum production of flowers, and complete pollination, red clover is potentially capable of yielding 12 bushels of seed per acre. Other investigators put the maximum yield of alfalfa at 40 bushels per acre. We will probably never reach such yields, but in view of such potential yields we should certainly not be overly optimistic if we attempt to produce 3 bushels of red clover seed and 5 bushels of alfalfa seed per acre.

Few people appreciate the magnitude of producing 5 bushels of alfalfa seed per acre. There are on the average about 200,000 alfalfa seeds per pound or approximately 12,000,000 per bushel, according to statistics in the United States Department of Agricultural Yearbook for 1948. Since a single alfalfa flower will produce between 2 and 3 seeds per pod, a minimum of 4,000,000 flowers or 92 per square foot must be visited and pollinated to produce one bushel of seed. To produce an average of five bushels of seed, 20,000,000 flowers or 460 per square foot must be pollinated. If the 5000 acres harvested for alfalfa seed in 1947, Justin *et al* (7), had produced five bushels of seed to the acre, it would have been necessary to pollinate a total of one hundred billion flowers.

Red clover pollination requirements are even more startling. Each pound of red clover seed contains approximately 275,000 seeds, (USDA Yearbook 1948), or 15,500,000 per bushel. Since each clover flower produces only one seed, 15,500,000 pollinations are necessary to produce a bushel of red clover seed. An average clover head contains from 125 to 175 individual flowers. If we should obtain a minimum of 25 pollinations per head, it would require a total of 620,000 heads or 15 per square foot to produce a bushel of seed per acre. To produce three bushels of seeds, 46,500,000 flowers, 1,860,000 heads, or 45 heads per square foot will be needed. In Indiana in 1948 there were 291,000 acres of red clover harvested for seed, Justin *et al* (7). If each of these acres was to produce three bushels of seed, there would have to be a total of four trillion, five hundred ten billion, five hundred million flowers pollinated or one hundred eighty billion four hundred million heads containing 25 pollinations each.

Pollination of Alfalfa

In most areas of the more humid regions, honeybees are notoriously inefficient pollinators of alfalfa. This is due principally to the peculiar structure of the alfalfa flower which makes it difficult for honeybees to obtain pollen. The reproductive parts of the alfalfa flower, commonly called the "sexual column," consist of the pistil and the stamens. This column is enclosed by the keel petals and is under a tension when the flower is fully opened. When pressure is exerted on the keel petals this sexual column springs forward with considerable force. The stigma of the pistil first strikes the pollinating insects followed by the anthers which dust the insect with pollen. This mechanism insures cross-pollination which is necessary to produce vigorous plants and good seed yields. This process of releasing the sexual column is known as "tripping" and very little if any seed will be produced if the flowers are not tripped. Honeybees collecting nectar soon learn to avoid tripping alfalfa flowers because of the force of the released column and secure the nectar from the side of the flower by inserting their proboscis between the wing and standard petals. Pollen collectors usually seek other sources of pollen when available. However, most investigators report that the honeybee while collecting nectar from alfalfa flowers will trip as high as four percent of the flowers by accident. Under average conditions the best estimates place the maximum tripped at two percent. Nectar collecting honeybees when present in large numbers will tend to compensate for their low efficiency of tripping and may be responsible for a considerable seed set. If honeybees can be induced to work alfalfa for pollen their efficiency is very high and they will be responsible for high seed yields.

In the western areas of the United States, where most of the alfalfa seed is produced, the honeybee is the main agent of pollination. These areas are largely isolated valleys which are under irrigation and where competing nectar and pollen plants are at a minimum. Hare and Vansell (5), found that at Delta, Utah, honeybees collected 32.4% of the pollen from alfalfa, 42.0% from greasewood, and 16.0% from corn, sweet clover, and cockle-bur. Since alfalfa was the main crop in this area, the low percentage of pollen from corn, sweet clover, and cocklebur was probably due to the small numbers of these plants in the area. In the humid areas honeybees are rarely found collecting pollen from alfalfa flowers, as there are generally many other sources from which pollen can be more easily obtained.

The question arises can honeybees be of any value in producing alfalfa seed? A strong colony of honeybees will contain approximately 60,000 individuals. According to Park (9), about ⅓ or 20,000 of these will be field bees. Various authorities (4, 9, 10) estimate that from 2.8% to 5% of these field bees will be pollen collectors. This means that if we take 4% as a suitable average for pollen collectors, 96% or 19,200 bees from a colony of 60,000 individuals will be collecting nectar. Park (9) estimates that the average life of a field bee is 20 days during which it will make an average of 10 trips a day for nectar. If we take the average tripping efficiency of the nectar-collecting honeybee as 1.5%, each bee would have to visit 347 flowers per trip to cause sufficient tripping to produce five bushels of alfalfa seed. This would mean an average of 4 honeybees per square yard. If we assume that a minimum of 350 alfalfa flowers are necessary to produce a bee-load of nectar, and if these nectar-collecting field bees could be confined to one acre, they could trip sufficient flowers to produce a 5 bushel yield of alfalfa seed.

Some experimental work has been done in the area east of the Mississippi river which has given definite indications that concentrated populations of bees in alfalfa will produce good yields of seed. Drake (2) reports the results of the use of bees in pollinating alfalfa in eastern Nebraska which corroborates the experimental results nearer Indiana. In this study, 256 colonies of bees were placed in a 250 acre alfalfa field. Parts of this field were cut for hay on each of three different dates with intervals of 8 to 10 days, which resulted in prolonging the period of bloom of the seed crop. As a result, he reports that 2050 bushels of cleaned alfalfa seed were harvested and 7 tons of extracted alfalfa honey was produced from these 250 acres. This averages a little more than 8 bushels of clean seed per acre, indicating that the honeybees collected some pollen from the alfalfa or that the nectar-collecting bees were augmented by sufficient native bees to increase the seed yield above five bushels. It would appear that honeybees may be able to do an adquate job of pollination in alfalfa.

The beekeeper who is willing to place his bees at the service of the alfalfa seed grower should keep in mind the following points, if a maximum amount of honey as well as a good seed yield is to be obtained.

1. Harmful insects must be controlled. Plantbugs when present in numbers as few as 7 or 8 per sweep can completely destroy the bloom of the alfalfa plants. Leafhoppers will also seriously affect seed yields. Wilson (12) in the vicinity of West Point, Indiana, found that one pound of DDT and one-half pound of Chlordane per acre, applied as a wettable powder spray at the prebloom stage of growth gave excellent control for a period of four weeks, and resulted in the best seed set. Insecticides if applied in the proper dosages at prebloom will not injure any pollinating insects.

2. Prolong the period of blooming by cutting parts of the field at least three different times, a week to 10 days apart. This will result in greater concentration of bees in the blooming part of the field with resultant increase in pollinations. The longer period of bloom will allow the colonies to build up with consequent heavier honey yields.

3. Hay cuttings of competing crops should be made where possible to reduce sources of more easily available nectar in the vicinity.

4. Not less than one colony per acre should be used and the bees should be located in the field or closely adjacent if possible. Best results would probably be obtained if the colonies were dispersed in the field, but the distribution will have to be adjusted to reduce the labor of examining the bees.

Pollination of Red Clover

The attraction of honeybees to red clover is the reverse of their attraction to alfalfa. Pollen-collecting field bees readily work red clover flowers, but the nectar-collecting bees are indifferent to them. This is due mainly to a physical incompatibility between the bees anatomy and the anatomical structure of the red clover flower.

Measurements given by Martin (8), indicate that the average length of the corolla tube of a red clover flower is 9.2 mm. The tongue of the worker honeybee averages 7.37 mm. Since the nectar rarely rises over 1 mm. in the clover flower corolla it is obvious that the tongue of the worker honeybee cannot reach the nectar. Although some flowers may be slightly shorter than the average, these are not sufficiently numerous to make the clover plant attractive to nectar-collecting bees. Measurements of the quality of red clover nectar indicate that it compares favorably in sugar content to that of other flowers which do attract the honeybees. It seems apparent that the small quantity of nectar produced and its unavailability are responsible for this indifference on the part of nectar-collecting bees. Bumblebees, which are well known as pollinators of red clover have much longer tongues and can readily obtain the nectar from the flowers.

Attempts have been made to breed red clover varieties with shorter corollas. In every case the attempt has failed. It was found that short corollas are generally associated with inherent weaknesses in the plants or with peculiarities of environment. With the development of controlled breeding of honeybees through artificial insemination, it may become possible to breed a strain of honeybees with longer tongues. However, there is no information at present that the variability of tongue length in honeybees is sufficient to warrant an attempt to breed longer-tongued bees.

The problem of red clover pollination lies in the inability of nectar-collecting bees to obtain the nectar in the clover flowers, and the competition of other sources of pollen at the time the clover plants are in flower. Honeybees will readily collect pollen from clover blossoms and in so doing assure pollination of the flowers visited. Beard and Dunham (1), showed that in north-western Ohio, 82% of the clover pollination was accomplished by honeybees, 15% by bumblebees, and 3% by miscellaneous insects. The authors recommend growing red clover for seed in the vicinity of large colony sites, or enticing beekeepers to locate their yards near clover seed fields by offering free colony sites. They imply that honeybees can be depended on to pollinate red clover. However, since red clover in most years will not produce sufficient nectar available to honeybees, other inducements besides free colony sites will have to be offered. The beekeeper, no matter how altruistic and philanthropic he may be, is in the business to earn a livelihood, and depends on honey and associated products for his income.

Red clover must be cross-pollinated to produce seed, and since only pollen, collecting field honeybees will pollinate red clover flowers, the successful use of honeybees for this purpose will depend on a strong colony putting enough pollen-collector's in the field during the flowering period, to pollinate the number of flowers necessary for economic seed production. As stated previously, 46,500,000 flowers must be pollinated to produce three bushels of seed. Under the discussion of the use of honeybees to pollinate alfalfa, it was estimated that a colony of 60,000 bees will put 20,000 bees in the field, of which approximately 4% or 800 will be pollen collectors. Using the estimate of 20 days for the life of the field bee and 8 pollen trips per day (Park, 9), each pollen-collecting field bee must visit 363 flowers on each trip to pollinate sufficient flowers to produce three bushels of seed per acre. Dunham (3), has stated that to obtain a full load of pollen, a bee must visit 346 florets. This figure is slightly less than the estimated requirements, but falls well within the limits of error in obtaining these estimates. By using several cutting dates for the hay crop to prolong the blooming period, one colony per acre should be able to pollinate sufficient red clover flowers to produce a yield of 3 bushels of seed.

Farmer and beekeeper opinions as reported by Martin (8), from Iowa show very diversified opinions as to the value of honeybees for red clover seed production. Martin states, "it is lamentable, (this diversified opinion), in view of what is being done in European countries where honeybees are well known to be of value in red clover seed production and are systematically and effectively used to increase yields to as much as 8 bushels in some countries. European red clovers are very similar in length of flowers and amount of nectar secreted to American clovers. The successful use of the honeybee to pollinate red clover in the United States has yet to be worked out." It appears that the problem is not insurmountable.

Since bees will only work red clover to obtain pollen, it is obvious that the beekeeper will not be interested in red clover seed production unless he receives some type of remuneration. There are several ways this may be accomplished depending on the localities and the individuals involved.

1. Direct rental payments at so much per colony. In such case written requests for such service and an agreement on payment should be made, as the grower assumes all risk for failure of his seed crop. Many factors other than inadequate pollination can cause seed losses.

2. Sharing seed yields with the beekeeper. Under such an arrangement the seed grower and beekeeper agree to share all seed above a base amount (usually one bushel) on a percentage basis, usually 50-50. This type of agreement is receiving serious consideration in many localities.

3. The seed grower agrees to plant some crop as a source of nectar supply for bees placed in the vicinity of his clover seed fields. Under this type of arrangement, the grower agrees to plant a specified number of acres of some nectar secreting crop in return for the services of the bees to pollinate the red clover crop. This would assure the beekeeper a honey crop as his payment and the seed grower would obtain the services of the pollen-collecting bees to produce a seed crop. The main point to be considered under such an arrangement will be to plant a nectar crop such as sweet clover or alfalfa which will not compete with the red clover as a source of pollen. If the use of honeybees should become widespread under such agreements, the disposal of the surplus

honey might become a problem. This type of agreement has been used extensively in Wood county, Ohio.

Injurious insects are a complicating factor in red clover seed production. Many more insects attack red clover than are at present injurious to alfalfa. Those attacking the roots and foliage weaken the plant or may completely destroy it, thus reducing stands and presenting a hazard to second crop seed production. Other insects attack the heads directly and present the problem of control without injury to pollinating insects. The use of DDT on any forage crop that may be fed to lactating animals and those being prepared for the market must be avoided in order to prevent the presence of DDT in milk products and in the fatty tissues of meat for human consumption. This means that if the grower treats his field for insect control as a step in seed production, failure of seed set from any other cause will not permit him to use the crop for hay or grazing, except under certain restrictions.

The use of honeybees for pollinating red clover then follows the same procedure as those for alfalfa with a few modifications.

1. Although the control of injurious insects on red clover by prebloom treatment is still in the experimental stages, it is recommended as a precautionary measure. Methoxychlor may be substituted for DDT, but should be used with chlordane to control plantbugs. The use of methoxychlor in place of DDT, makes possible use of the crop for forage in event of seed failure under present Pure Food and Drug rulings. If properly applied in correct dosages and at the prebloom stage of growth, no injury from insecticides will occur to pollinating insects.

2. Prolonging the flowering period of the red clover may be less desirable than in alfalfa, unless the bees have a source of nectar available to maintain colony strength. Colony strength may also be maintained by feeding, but this involves additional expense and labor. If an additional source of nectar is available, cutting the hay crop at intervals of 8 to 10 days will result in a greater concentration of bees in the clover in flower at any one time, and consequently a chance for a larger seed set.

3. Avoid competing crops as sources of pollen supply. The knowledge of the beekeeper should make possible the removal of competing sources of pollen, or if a crop is apt to compete some adjustment of planting or cutting time should be made to avoid competition.

4. Not less than one colony per acre should be used, and if possible locate the bees in the field to be pollinated or as close as practical. Shading of the colonies if necessary can be accomplished by the use of light frames and cloth, which can be removed for examinations of the bees.

The assistance of seed growers and beekeepers in experimental studies and the opportunity to make observations when bees are utilized for legume pollinations are greatly needed if we are to solve the problems of using honeybees as pollinating agents in legume fields, thereby creating more opportunities for beekeepers through a greater demand for honeybees.

Summary

Reductions in numbers of native pollinating insects throughout the greater portions of Indiana have resulted in decreased yields of legume seed, and have stimulated interest in the use of honeybees to pollinate alfalfa and red clover. These crops present the greatest problems in pollination.

Pollen-collecting honeybees will not work alfalfa flowers in this area as more easily available sources of pollen are usually present. However, the nectar-collecting bees readily work alfalfa flowers, and although only one to two percent efficient, there are sufficient nectar-collecting field bees in a colony of 60,000 bees, to trip the flowers necessary to produce approximately five bushels of seed per acre.

Although red clover nectar contains adequate amounts of sugar, honeybees usually cannot obtain it due to the length of the clover flower corollas which are approximately 2 mm. longer than the tongues of the honeybees. Pollen-collecting field bees will readily work red clover flowers. There is a sufficient number of pollen-collecting field bees in a colony containing 60,000 bees, to pollinate the flowers necessary to produce three bushels of red clover seed per acre. Since beekeepers cannot generally expect a honey crop from red clover, some method of remuneration for placing colonies of bees in red clover seed fields must be arranged. Such methods include direct rental, sharing seed crop, and providing nectar crop.

Points to be observed in the use of honeybees for pollinating legumes include prebloom treatment of the crop for injurious insect control; staggering of first crop hay cuttings to prolong the flowering period; elimination of competing crops as sources of nectar or pollen; and, using not less than one strong colony of bees per acre.

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The German Roach as a Laboratory Test Animal[1]

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The German cockroach, a common pest of kitchens, makes an excellent "guinea pig" for the preliminary testing of new insecticides in the laboratory. It can be reared in large numbers in the laboratory and is easily handled in the testing procedures. The use of this small insect provides a rapid screening method for chemicals whereby an estimate of their insecticidal value can be determined in the laboratory before more extensive tests are made in the field.

The present stock of roaches in our laboratory has been maintained with no difficulty for 12 years. The procedure followed in rearing roaches is to select 300 young females and 150 males about May 1. Approximately 20 females and 10 males are started in each of 15 glass battery jars. In each jar are placed a cotton-stoppered vial of water and an inverted paper cup. The cup has two small pieces cut out of the rim to permit the roaches to crawl inside the cup for protection. Food, a pellet form of commercial dog food, is placed on top of the paper cup. Roaches are kept in the glass jar by an inch band of vaseline around the inside of the mouth and by cheese cloth held in place over the mouth by a rubber band.

During the summer months the roaches are allowed to live and reproduce in the jars. They require only such attention as supplying water and food once a week and cleaning out the debris every two weeks. The trouble from mites killing roaches, experienced in some laboratories, has been avoided by cleanliness and by separating food and water to prevent the growth of mold. By early August each jar has a large population of about 200 adults and perhaps 1500 nymphs. When the jars become crowded, the entire lot is dumped into the large stock cage.

The stock cage consists of an outer wooden box 24 by 30 inches and an inner cage 19 by 24 inches. The outer box has 8 inch sides which are lined with a 7 inch continuous piece of celluloid. The inner cage consists of a wooden frame of 1 by 2 inch lumber with a screen-wire bottom and 6 inch celluloid sides. The celluloid attached to the wooden box is coated on the inside with a thin film of vaseline, while both sides of the inner celluloid walls are coated. Roaches are placed in the inner cage, where the adults are retained by the vaseline-coated walls, while the young can go through the screen-wire into the larger wooden box. Although the top is open, adults cannot fly out. The small nymphs occasionally crawl over the vaseline and so a band of sodium fluoride is kept on the table around the cage. Ground dog food is supplied by inverting a four-ounce glass jar on two small pieces of wood set in a petri dish. Water is supplied in the same manner except that a piece of screen-wire is placed under the jar openings to prevent entrance and subsequent drowning of roaches.

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Roaches from the 15 battery jars are placed in the stock cage about August 1 and in two weeks a number of newly-hatched nymphs has accumulated. To remove the young the inner cage is tapped several times and then set out on a piece of paper previously prepared with a two inch band of sodium fluoride slightly larger than the bottom of the cage. The young are now exposed in the outer box and are picked up with a "suck" bottle for transferring to the glass battery jars. Subsequent lots are transferred to the jars at weekly intervals and thus give roach populations of known ages.

The length of time required for nymphal development varies with the temperature of their environment. According to previous studies (6) this period ranges from 103 days at 70 to 75°F to 74 days at 83 to 86°F. As the roaches mature, they are removed from the stock jars and are separated according to their sex. These roaches are ready for use in the insecticide tests on the following morning. The roaches not used in the tests are placed in the large stock cage in order to replenish that supply.

This rearing procedure has been followed for the past eight years and has provided an ample supply for testing by about October 15. The settling dust method of testing insecticides has also been followed for eight years and has been described in previous articles (2, 3, 4, 5). It consists, in brief, of blowing the insecticide up in a tower and permitting it to settle for seven minutes on a 5 by 5 inch wooden tray. Then the tray is taken out of the cylinder and 10 or 15 roaches introduced. The roaches run through the film for seven minutes and then are transferred to clean jars for observation for 96 hours.

The rapidity of roach development is of interest not only to the housewife but also to the laboratory worker. Previous studies by Gould and Deay (6) indicate that at a room temperature of about 76°F incubation of eggs requires 28 days and nymphal development about 95 days. In order to estimate the possible number of offspring in one year from a pair of roaches, the figures of the earlier studies (6) have been used. Suppose we assume the start of this colony May 1 with one female and one male and that half the offspring produced are females. The German female produces five capsules during her adult life of about six months. If the capsules contain an average of 32 individuals and all survive and reproduce, then the population the following May would consist of 3200 adults and 37,376 nymphs and a year later of 3,000,000 or more.

The American roach has also been used as a test insect but is not so well adapted for rearing. It requires 15 to 18 months to mature and being larger needs more space and food. Usually when this roach is used, it is trapped as needed. Burnett (1) and others have stated that the American roach is more prolific, as a female produces 1440 eggs as compared to 160 for the German Roach. This is true but the American has a much longer developmental period and would have about 1200 offspring, all nymphs, in a 12 months period as compared with the 40,000 for the German.

The advantages of using the German roach for laboratory testing are many and include ease of culture, low cost of rearing, rapid rate of reproduction, small rearing space, species readily available, species representative of a group, species economically important in itself, and the results are applicable to other species. According to a survey of test insects used by entomological laboratories, the National Research Council (Mimeograph report, October, 1949) found the German roach second to the housefly in a list of 192 insects. The American roach was used frequently, while a few laboratories listed the Oriental roach, the brown-banded roach and the smoky brown roach.

Variation in susceptibility to insecticides of different insects and by different stages of the same insect has been noted by many workers. Among roaches the fifth instar is considered the most difficult to kill, followed by the adult female, the fourth nymphal instar and the adult male. In our tests both males and females were used until 1948 when females alone were used. In table I the effectiveness of some common

TABLE I. Comparison of the kill of male and female German cockroaches treated with certain insecticides, 1947.

Insecticide and per cent of active ingredients		Males		Females	
		Per cent kill	Survival time in hours	Per cent kill	Survival time in hours
Sodium	5	52	73	14	90
fluoride	10	86	64	32	74
	25	92	53	74	68
D.D.T.	0.75	34	59	28	76
	1.0	85	51	46	63
	2.5	100	41	68	71
Benzene	0.1	50	58	20	74
hexachloride	0.2	100	31	94	42
	0.3	100	35	100	56
Lindane	0.1	11	72	5	
	0.3	67	54	35	62
	0.5	100	22	86	55
Toxaphene	0.5	82	78	33	80
	0.75	97	68	42	86
	1.0	100	61	80	81
Parathion	0.03	42	45	20	52
	0.05	92	37	70	44
	0.1	100	25	98	38
Chlordane	0.5	56	78	22	90
	1.0	98	52	83	83
	2.0	100	57	89	74

chemicals against the two sexes is compared. The averages given in the table are based on 10 tests of five roaches each. The kill of males was from 20 to 270 per cent better than that of females. An average of the 13 comparisons in the table show a 70 per cent kill of males and a 40 per cent kill of females. The response of the two sexes to the action of some insecticides shows a high degree of correlation. Since the females in these tests and in most others made between 1941 and 1947 were nearly twice as difficult to kill as the males, females alone have been used in most tests in the past two years.

Several hundred mixtures have been tested in the laboratory during the past seven years and results of 1943 to 1947 have been published (2, 3, 4, 5). In the 1948 and 1949 tests two changes were made in procedure: first, females were used in most tests and, second, dilutions of the active ingredient were reduced to a point where kills were less than 100 per cent. In the past there has been no method of comparison where two materials killed all roaches. By the use of lower dilutions three or more values giving less than 100 per cent kills can be plotted on logarithmic probability paper (Wadley, 7). When the three or more points are located, a straight line can be fitted to them.

The data on females for 1947 (Table I) were the first to be plotted on log probability paper. For 1948 (Table II) and 1949 the complete series of 10 tests for each material was run only on the females. The straight lines for these materials are shown on the accompanying graph (Fig. 1). Where these lines intersect the line for a 50 per cent kill, a value for each in terms of percentage of active ingredients can be ascertained. If the quantity for the best material is assigned a value of 1, then the comparative values of the other materials can be established. These values based on the per cent active ingredients necessary for a 50 per cent kill are as follows:

Material	Per Cent Active Ingredient	Value
Compound 497	.031	1.0
Parathion	.042	1.3
Compound 118	.0715	2.3
Pyrethrins in pyrethrum powder	.107	3.5
Benzene hexachloride (gamma)	.123	4.0
Lindane (gamma)	.283	9.1
Chlordane	.425	13.7
Toxaphene	.71	22.9
DDT	1.1	35.5
DDD	3.0	97.0
DMDT	4.7	151.6
Sodium fluoride (males)	4.8	154.8
Fluoro DDT	8.6	277.4
Sodium fluoride (females)	13.5	435.5

TABLE II. The percentage of kill and the survival time in hours of female German roaches treated in the laboratory in a settling dust chamber with various strengths of insecticides. Prophyllite was used as diluent in all mixtures. 1948.

Material	Per cent active ingredient	Per cent kill	Survival time
Rotenone (5% cube)	3.0	0	
Rotenone extract (34%)	2.5	12	75
Rotenone extract .	5.0	62	65
Rotenone extract . .	7.5	42	46
Rotenone extract plus 1% piperonyl butoxide	1.0	8	
Pyrethrum powder (0.3%) . ..	0.075	18	52
Pyrethrum powder	0.1	28	61
Pyrethrum powder . .	0.15	86	43
Pyrethrum extract (20%) impregnated	0.25	20	62
Pyrethrum extract .. .	0.375	38	60
Pyrethrum extract . . .	0.5	86	46
Pyrethrins plus .25% piperonyl cyclonene impregnated separately and mixed	0.25	0	
Same mixed as liquids and impregnated	0.25	40	67
Pyrethrins plus .50% piperonyl cyclonene	0.50	86	37
Pyrethrins plus .50% piperonyl cyclonene .	0.2	84	58
Pyrethrins plus .25% piperonyl butoxide	0.25	70	46
Pyrethrins plus .125% piperonyl butoxide	0.125	8	
Pyrethrins plus .50% piperonyl butoxide	0.5	96	37
Pyrethrins plus .20% piperonyl butoxide	0.2	68	57
Pyrenone T127 (pyrethrins and p. cyclonene)	0.02	0	
Pyrenone T127	0.04	20	48
Pyrenone T127 .	0.06	38	38
Pyrenone T127	0.1	70	52
Pyrenone T166 (pyrethrins and p. butoxide)	0.02	4	
Pyrenone T166 . .	0.03	28	46
Pyrenone T166	0.04	67	49
Pyrenone T166	0.05	76	46
D.D.T. 50% wettable powder.	2.5	80	80
D.D.T. 100% impregnated on powder .	2.5	71	81
D.D.T. 50% wettable aerosol grade	2.5	88	78
pp'D.D.T. 100% powder	2.5	16	72
D.D.T. 100% powder	5.0	33	84
Ditolyl trichloroethane 25% powder . .	2.5	6	
pp' isomer of above..	10.0	0	
Fluoro D.D.T. 100% impregnated in powder	2.5	2	
Fluoro D.D.T.	5.0	26	90
Fluoro D.D.T.	7.5	40	69
Fluoro D.D.T..	10.0	58	91
D.D.D. 50% wettable powder...	2.0	22	85
D.D.D.	4.0	78	79
D.D.D.	6.0	86	74
Methoxychlor 50% wettable powder	2.5	10	
Methoxychlor	5.0	60	58
Methoxychlor	7.5	78	63
pp' isomer of above 50% wettable powder .	2.5	0	
pp' isomer	5.0	10	74
pp' isomer	10.0	12	75
Chlordane 5% dust	0.3	21	90
Chlordane	0.5	62	71
Chlordane	0.75	93	71
Chlordane..	1.0	100	66
Toxaphene 50% powder.....	1.0	82	77
Sodium fluoride	17.5	66	74

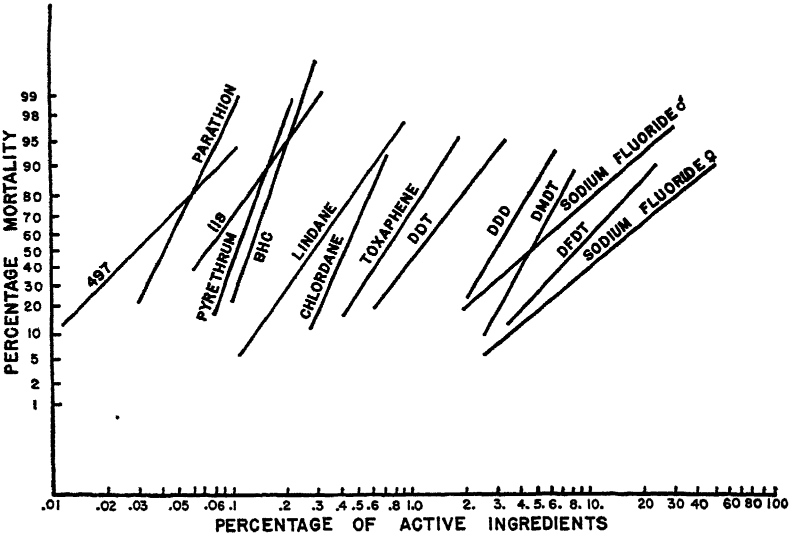

Figure 1. The percentage mortality of the female German roach exposed to different concentrations of insecticides.

In the tests of 1949 (Table III) considerable attention was given to the non-poisonous materials, pyrethrum and rotenone. These materials were used alone and in combinations with activators. Rotenone in the form of cube powder produced no mortality, while the extract gave a low kill. The addition of the activator, piperonyl butoxide, to the extract produced no measurable response. On the other hand the addition of either piperonyl cyclonene or piperonyl butoxide greatly increased the effectiveness of pyrethrum extract. The butoxide gave better results as a 50 per cent kill was obtained with .037 per cent pyrethrins while the cyclonene required .07 per cent of the pyrethrins for the same kill. Pyrethrum extract alone required .37 per cent active material for a 50 percent kill, while pyrethrum powder required .11 per cent. In the preparation of laboratory mixtures it was found that the liquid pyrethrum extract had to be combined with the liquid piperonyl material before they were impregnated on the dust. Of the many laboratory mixtures prepared with pyrethrum none were as effective as the commercial preparation.

In the second series several of the new chlorinated hydrocarbon materials were compared. A dust prepared from a standard DDT wettable powder was more effective than dusts prepared from the pp'isomer and the technical DDT, but was less effective than the dust made from the aerosol grade of DDT. DDT was better than the fluoro and tolyl analogs of DDT. It was also better than DDD and methoxychlor, but was less effective than chlordane and toxaphene.

In 1949 two new compounds were tested along with several of the older materials. Considerable variation was found in the results from

TABLE III. The percentage of kill and the survival time in hours of female German roaches treated in the laboratory in a settling dust chamber with various strengths of insecticides. Pyrophyllite was used as diluent in all mixtures. 1949.

Material	Per cent active ingredient	Per cent kill	Survival time
Compound 118-K-W	0.075	63	84
	0.1	66	72
	0.175	82	81
	0.25	98	63
Compound 497	0.01	14	92
	0.03	36	94
	0.05	75	81
DDT 50% wettable powder	1.0	23	92
	1.5	45	70
	2.0	65	75
DDT micronized 50% wettable powder	1.0	42	85
	1.5	54	67
	2.0	84	79
Fluoro DDT	2.5	31	67
	5.0	71	58
	10.0	94	51
Chlordane	0.5	62	76
Toxaphene	0.35	24	47
	0.4	34	86
	0.5	92	72
CS-645A	2.0	26	54
Sodium fluoride	10.0	28	86
	17.5	57	81
	25.0	70	51

different laboratory mixtures and between commercial mixtures. This variation was especially noticeable when a commercial mixture was compared with a laboratory mixture. The process of manufacture also influenced results as indicated in the difference between a micronized and a regular DDT. The finely ground material gave 10 to 20 per cent better kills at the various dilutions. A sample of fluoro DDT gave better kills this year than did the sample from another company used in 1948.

The two new compounds, No. 118 and No. 497, gave excellent results with roaches. Several samples formulated by different companies or at different times by one company showed variable results but in general were about as good as parathion. Another new chemical, 2-Nitro-1,1-bis(p-chlorophenyl) propane, (CS-645A) showed some toxicity to the roach, as it killed 26 percent at a 2 per cent dilution. Two mixtures prepared by a graduate student in chemistry and designated as Cl 12 and R103 showed no toxicity to roaches.

Summary

The German roach has been used in the laboratory for the past eight years as a test insect in the evaluation of insecticidal efficiency.

Because of its ease in rearing and its rapid rate of reproduction this insect has proven itself to be an excellent "guinea pig" in the study of insecticides. These preliminary tests in the laboratory have given a comparative rating of many new materials and have indicated those materials worthy of further tests in the field.

Of the materials used in the past eight years the compound 497 has given the best kill. Other materials in order of decreasing efficiency are parathion, No. 118, pyrethrins in pyrethrum powder, gamma-benzene hexachloride, lindane, chlordane, toxaphene, DDT, DDD, DMDT, DFDT, and sodium fluoride. Pyrethrum extract activated with one of the piperonyl compounds gave an excellent kill and on the basis of pyrethrins only would rate near 497.

A high rating in these tests does not necessarily indicate that the material would be of practical value in roach control. Many of these materials are highly toxic to humans and consequently would be of little value in the home and around food manufacturing plants or storage. Among the recommended treatments pyrethrum powder and activated pyrethrins are foremost in the contact materials and chlordane oil solution as a residual treatment. DDT, chlordane dust and even sodium fluoride are still of value against certain roaches and in certain locations.

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The Control of Insects in Sod Culture Peach Orchards

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Looking at a map of Indiana, which shows the areas set aside for reforestation, one will observe a great number of such projects in the south-central counties. Here a large part of the land area has been eroded until it is unfit for general farming. Still more thousands of acres are being farmed in such a manner that within a few years they will be almost worthless. The growing of peaches has contributed its part toward the loss of our land.

For years growers have been taught that clean cultivation is necessary in growing peaches regardless of whether or not the land is rolling or relatively level. Accordingly, where the orchards have been planted on rough land the productive period of the land is often limited to the life of one peach orchard. However, during the last few years through studies in progress we have learned that very remunerative peach crops may be grown on land kept in sod. This work is being carried on at the Fruit Insect Research Orchard of the Purdue University Agricultural Experiment Station at Orleans, Indiana, and was undertaken in order to study its effect upon insect populations and their control.

First to be considered in growing peaches in sod is the availability of moisture and soil fertility maintenance. During the past three years Gage Elberta peaches planted in 1941 and maintained under sod culture have shown no signs of drought. Through the application of a pound of nitrate a year for each year of age of the trees in 1949 this orchard began to show evidence of too much nitrogen.

Two diseases which thrive under sod conditions in peach orchards are brown rot and scab. Brown rot especially has been a problem in sod or even weedy orchards. This is caused to a great extent by the fallen peaches which cannot be easily picked up and destroyed. Our present work is showing that if sod and weeds are kept cleaned out from beneath the trees, over the area just large enough that all dropped peaches fall on clean ground where they may be easily seen and removed, this peach disease remains a very minor one. Cutting the sod from beneath the trees only permits the growth of grass over the remaining areas of the orchard. To keep the area beneath the trees clean the ground will need to be hoed at least twice during the summer season and the drops picked up periodically. The cost of the operation in this study has been found to be 65 cents per tree for trees returning a crop which sold for almost $14.00. Under such treatment and for the past several years not more than two sprays have been applied for brown rot control and these have become more necessary against scab than to control brown rot.

Two insect pests which have in the past given considerable difficulty in control whether the orchard is in sod culture or not are the plum curculio and the Oriental fruit moth. Lead arsenate with plenty of lime or chlordane applied as suggested in the Indiana spray schedule will control the plum curculio very satisfactorily. The Oriental fruit moth has ceased to be a problem of importance where DDT sprays can be applied at intervals of five to six days during the third brood of the insect.

Spider mites on the peach orchard became a problem for the first time in 1949. Only one spray application of parathion applied August 2 was needed for excellent control. This spray was put on when the mite count averaged 30 per leaf. A portable Bean sprayer was used. The operator drove down each tree row and before spraying the outside of the tree he sought an open place under it and without going under sprayed the opposite side of the tree from beneath. No particular effort was made to be certain that every part of the under side was hit. However, inasmuch as this operation was carried out in each row both sides of the under part of the tree was sprayed. Examinations indicated that the mite population was kept under control.

The tarnished plant bug and pentatomids, which cause cat-facing of fruit, present what is at present the only remaining threat in sod culture of peaches. The insects which cat-face the fruit are certainly more destructive under sod conditions than under clean culture, however, the type of vegetation which surrounds the orchard seems to be more important than sod within the planting. As we have studied this problem it has been found that fruit damage is greater in years in which the fruit set is light and when alfalfa or clover instead of corn is planted in adjacent fields. Under conditions existing at this station the tarnished plant bug causes greater damage than do the pentatomids.

In 1949 thinning was finished on June 14. At that time, all the cat-faced peaches were removed. Between this date and August 6, the percentage of peaches injured by lygus and pentatomid bugs was as great as it had been before thinning time. About June 6 the dimpling caused by tarnished plant bugs stopped and from that time on points of attack on the fruit were marked by exudes of wax. Often these hardened wax exudes stand out pedestal-like a quarter of an inch or more from the fruit. In other instances the wax flattens out on the surface of the peaches and dries hard and shiny.

Caged lygus bugs were put over uninjured peaches each week beginning May 14. When they could be found, pentatomid species were likewise caged separately over the uninjured fruit. The date when the pentatomids no longer cat-face peaches is not certain because it has often been impossible to find these insects when needed for caging. Lygus bugs are rather difficult to collect and cage without injury to the insects. Often the caged bugs died the same day they were put on the fruits. Observations of insects which lived in cages one or more

TABLE I. Injury, if any, caused by caged bugs.

Date confined to cages over peaches	Lygus	caused injury	Pentatomids	caused injury
May 17	X	yes	X	yes
May 25			X	yes
May 27	X	yes		
June 2	X	yes		
June 6	X	yes		
June 14	X	yes		
July 6			X	No
July 19	X	yes		
Aug. 6	X	No	X	No
Aug. 12	X	No		

days were the only ones recorded. Table I gives the data gathered by this method.

Here the evidence indicates that injury by lygus does not occur after mid-July and that injury from pentatomids may stop as early as June 1. Field studies corroborate in some ways the cage studies.

An acre block of Gage Elberta trees planted seven rows one way and six the other were used to determine the severity of the attack by cat-facing insects. Counts were made by selecting the corner trees first. From each of these 100 peaches were examined for cat-facing injury. When these four trees were finished four others were selected. The position of the second four was two trees in from the corner ones toward the center of the block. This was repeated on two more which were at the center of the acre block. After these counts were completed, the record showed that trees which carried a very light load were not comparable with those carrying a full crop of peaches.

The following half dozen tree records show how uniformly catfacing increased in as many locations in the orchard before thinning.

Individual tree counts recorded as percent cat-faced fruits:

Counts taken May 14	8	7	4	13	16	9
Counts taken June 8	17	13	13	34	28	15

Thinning was finished on June 14. In the thinning operation every cat-faced peach was removed insofar as this was possible. A count of the number of cat-faced peaches was taken on August 16 using the same trees from which the counts of May and June had been made. The average number of peaches cat-faced per 100 each time counts were made were:

May 14	June 8	June 14	August 16
12.3	15.7	injured peaches removed	19.1

Thus it is seen that cat-facing injury in the field as in caged tests continued well after thining time—June 8. To control this type of injury a chlordane schedule was used. Here again cages were used to determine the effectiveness of the spray on both kinds of insects and incidentally on curculio. The insects were caged over the foliage and fruit as soon after spraying as the foliage was dry. The results obtained indicate that the kill of both curculio and lygus is practically 100 percent when 2.5 pints of 40 percent chlordane per 100 gallons is used but that only about half the pentatomids die. The study shows that a higher concentration of chlordane, another insecticide or a shorter interval between sprays is needed if effective control against cat-facing is effected. Inasmuch as cat-facing injury this past season has exceeded by far any other year since our studies began and since this is the first year chlordane has been used without being accompanied by lead arsenate and lime to control curculio it may be that lead arsenate-lime combinations have in the past been responsible to some extent for the lighter attack by cat-facing insects.

The Relation of Particle Size to the Toxicity of DDT Dusts[1]

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The purposes of this work were to find the most effective particle-size range of the toxicant DDT against the adult Mexican bean beetle, *Epilachna varivestis* Muls.; and to find which, if any, particle-size range of the diluent, *Pyrax ABB*, is the most effective in combination with DDT.

With the beginning of the investigations of the relation of particle-size to toxicity, it was found that generally the smaller particles of any particular poison were the most efficient for killing insects. However as more evidence was assembled it became apparent that a small-particle size of toxicant could not arbitrarily be rated as the most efficient killing size for all insects; and that any particular insect usually has a specific particle-size range for each particular insecticide or group of insecticides to which it is susceptible. Seigler and Goodhue (7) in tests on codling moth larvae found that there was little difference in the toxicity of coarse, medium and fine particles in calcium arsenate, Paris Green and cryolite samples, although the medium size was slightly superior to the coarse and fine. The respective sizes of these materials in their order listed were: 28, 5, 3 microns; 29, 10, 3 microns; 28, 8, 2 microns. Smith *et al* (9) observed that the coarse samples (samples containing the smallest percentage of particles below 5 microns in size) of Calcium arsenate caused the highest mortality to the boll weevil, and the larvae of the cotton leaf worm. Gaines (2) showed that the coarse sample of calcium arsenate was six times and the medium sample four times as toxic as the finest sample to fifth instar cotton leaf worm. McGovran *et al* (6) showed that the smallest particles of Paris Green, averaging 1.1 microns, caused the highest mortality and the least feeding; and the largest size particles, averaging 22 microns, gave the least kill and permitted more feeding among adult Mexican bean beetles. Smith (8) in tests on mosquito larvae found that the smaller particles were more toxic and induced more rapid paralysis than the larger particles because the fine powder covered more surface. With DDT, Woodruff and Turner (11) found that a reduction of DDT particle size caused an increase in toxicity of residues to the housefly. Also DDT dusts of the smallest particle size (10-20 microns) gave the best control of potato insects, particularly the potato flea beetle, and the heaviest yield of potatoes.

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[1] The data presented herein were obtained during the preparation of his thesis for the Master's degree at Purdue University. Contribution from the Entomology Department.

With regards to particle size of the diluent as effecting toxicity, Shipitzina found in 1935, as quoted from McGovran *et al* (6) in tests concerning the natural abilities of insect larvae to ingest different sizes of particles of insecticidal materials that "first-instar mosquito larvae *(Anopheles maculipennis messeae)* ingested quartz particles with maximum diameters ranging from 22.8 to 34.2 microns, and that fourth instar larvae ingested particles 68 to 165.3 microns in size." Chiu (1) found that in testing inert materials against the adult bean weevil, they are effective as killing agents, presumably because of the desiccating effect. The particles of finer sizes gave higher insecticidal efficiency. Hunt (4) found that abrasion is a primary action of a diluent in effecting toxicity of complete dusts, and that this abrasive action ultimately effects the speed of penetration of the toxicant present, and the desiccating effect of the dust upon the insects. The importance of these modes of action are, in turn, dependent upon climatic conditions, one particular set of climatic conditions favoring at any given time one or the other actions.

Materials and Equipment

The diluent for the dusts in this series of experiments was *Pyrax ABB* produced by the R. T. Vanderbilt Company of New York, and manufactured by the Standard Mineral Company of Robbins, North Carolina. According to Watkins and Norton (10) the material undergoes a milling and air-flotation process; the color is cream; the specific gravity is 2.84; the density is 30#/cu. ft. by the Scott volumeter; the average particles are flat, plate-like flakes. The average chemical analysis is as follows:

Ignition loss	4.00%
H2A12(SiO3)4	93.96%
MgO	0.02%
CaO	0.06%
K2O	1.54%
Fe2O3	0.07%
Na2O	0.20%
TiO3	0.15%

The DDT used for these tests was manufactured by Geigy Company Incorporated of New York. The material possessed a melting point of 90 degrees, and is known as a technical commercial type. According to Ginsburg (3) a sample of this chemical consists largely of two isomers, P,P'-DDT (1-trichloro-2,2-bis(p. chlorophenyl) ethane) and O,P'-DDT (1-trichloro-2,O-chlorophenyl-2-p. chlorophenyl ethane). These isomers are present in quantities that may vary from 70-80 and 15-20 per cent, respectively. In addition there are usually present in small quantities, other isomers, by-products and impurities. The material is white, somewhat damp to the touch and is composed of clotted clumps of irregular crystals.

Both of the dust constituents were separated into the various particle-size ranges separately on a Ro-Tap Test-in Sieve Shaker. The

Pyrax ABB was shaken for a period of one half hour, at which time the various particles had settled into their respective screen sizes (Figs, 1-5).

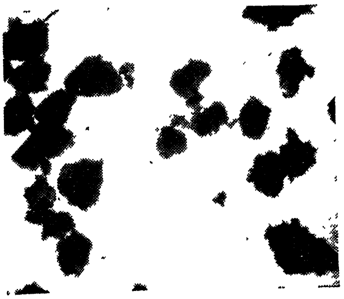

Figure 1. Microphotograph of DDT particles of size-range 104-149 microns (X110).

Figure 2. Microphotograph of DDT particles of size-range 74-104 microns (X110).

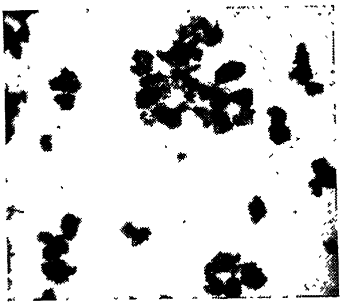

Figure 3. Microphotograph of DDT particles of size-range 53-74 microns (X110).

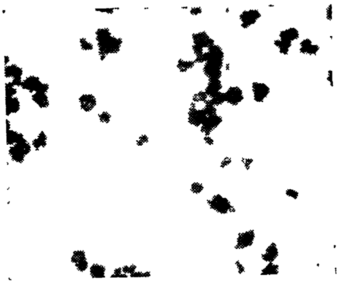

Figure 4. Microphotograph of DDT particles of size-range 44-53 microns (X110).

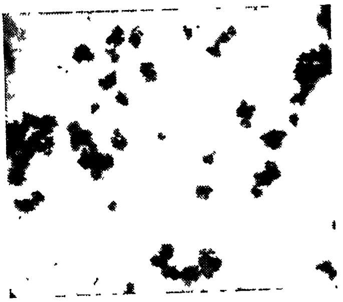

Figure 5. Microphotograph of DDT particles of size-range 0-44 microns (X110).

The sieve nest was then removed from the machine and each sieve was tapped separately to free the meshes of clogging particles. The nest then was replaced in the machine and shaken for an additional fifteen minutes. The DDT was treated in a like manner, except it was first ground in a mortar. Since the DDT caused extreme clogging of the sieve meshes, the sieved-out portions of DDT were removed at the end of the first half-hour, and the sieves were washed with carbon disulphide to dissolve the remaining DDT and dried. Then the DDT particles were placed in their respective sieves and shaken for the remaining fifteen minutes. The resulting particle-size ranges, the sieve sizes and their micron equivalents, plus the resulting particle-size analysis by this method of fractionation for the *Pyrax ABB*, are given in Table I. It was not possible to secure a reliable particle-size analysis for DDT, because of the excessive amount of clogged material that had to be dissolved out of the sieve screens. The various particle sizes of DDT obtained are shown in the microphotographs (Figs. 1-5).

TABLE I. The physical data of the sieving operation.

Sieve sizes in meshes per inch	Micron-size Equivalents	Micron-size ranges of sieved particles		*Pyrax* particle -size analysis
		DDT	*Pyrax ABB*	
100	149		Above 149[2]	0.16%
150	104	104-149	104-149	2.22%
200	74	74-104	74-104	0.83%
275	53	53-74	53-74	3.19%
325	44	44-53	44-53	6.11%
....	...	0-44	0-44	87.84%

[2] This particle-range size material was not used in the experiments.

The DDT and *Pyrax ABB* were mixed at a 2 per cent concentration by weight, as determined by preliminary tests for the L.D. 50. These materials were mixed in relatively small quantities, approximately 100 grams, because of excessive amount of time needed to obtain the various particle-size fractions by the sieving process. The mixing was done on a Model 10 Oster Mixer modified to the mixing of dusts. A 150 Watt bulb was put into the circuit as resistance to reduce the speed of the mixing blades to the point where the size of the particles was not affected. The upright mixing blades of the machine were inverted and another blade was added to create stirring in all parts of the mixing container. The original mixing container was discarded and a pint Ball jar was substituted. Each sample was mixed for fifteen minutes.

The testing cages used were 10-inch lantern globes covered at one end with cheese cloth. Six-inch, two-leaved *Stringless Greenpod* beans, grown in three-inch pots, were used as the testing plants. A turntable set to revolve once in three seconds was the dusting platform. The dusting equipment had as its air source the motor from a Hudson Electric-Spray, Paint sprayer 305. The dusting container consisted of an ordinary, insect suck-bottle, with a piece of glass tubing slightly drawn to serve as a nozzle. The speed of the duster motor was cut by inserting a 150 Watt bulb in the circuit to prevent excessive blowing and wasting of the dust material. Early second-brood and early third-brood adult Mexican bean beetles, *Epilachna varivestis* Muls., approximately one week old and collected in the field as needed, were used as test insects.

Experimental Procedures

The general plan of procedure for this series of experiments was to secure various particle-size ranges of DDT and similar particle-size ranges of *Pyrax ABB*, and test, as separate samples, all combinations of these two materials possible, within the limits of time and the material on hand. This plan resulted in the running of four series of experiments. In the first series, DDT and *Pyrax ABB* of the same particle size were mixed and tested; in the second series the largest DDT particles were mixed with Various *Pyrax ABB* particles; in the third series, the smallest-sized particles of DDT were mixed with the various *Pyrax ABB* particles; in the last series, the next to the smallest DDT particles were mixed with the various *Pyrax ABB* particles and tested. Table II lists the combinations of the dust mixtures used in these four series of tests.

Each sample of dust in a series was run on five plants at a time, each plant being infested with five beetles, making a total of 25 beetles per test for each sample. Each test was replicated five times, each on different days. Untreated checks were used with all tests. Checks treated with *Pyrax ABB* particles of the same size-range as those in the dust being tested were run with the first series of tests, but these were discontinued when no mortalities over the normal amount in untreated checks were produced. This non-toxic characteristic of *Pyrax* materials is indicated by Hunt (4) in his paper on the toxic action of diluents.

The five plants used for each sample were dusted at the same time by placing them on the dusting turntable together. The dust gun was held two feet from the plants during the dusting operation which lasted for six revolutions of the turntable. For three turns the dust was directed at the topside of the leaves, and for three turns at the lower side of the leaves. The 25 beetles for each sample test were placed together in a pint ice cream container covered with a layer of cheese cloth, and dusted therein for a count of three seconds. This method for dusting the insects was used as it was impossible to retain the beetles on the plants during the dusting operation. Lantern globes then were put over the plants and the beetles were added, five per plant. All of the tests of one replication of a series were run at the

TABLE II. The various dust mixtures for the four series of tests, showing the sample designations for each mixture, and the formulation of the mixture according to micron size of the DDT and *Pyrax ABB* particles.

Test Series	Sample	Formulation by Micron Size	
		DDT	*Pyrax ABB*
One	A1	104-149	104-149
	B1	53-74	53-74
	D1	44-53	44-53
	E1	0-44	0-44
	F1	Untreated	Untreated
Two	B2	104-149	74-104
	C2	104-149	53-74
	D2	104-149	44-53
	E2	104-149	0-44
	F2	Untreated	Untreated
Three	A3	0-44	104-149
	B3	0-44	74-104
	C3	0-44	53-74
	D3	0-44	44-53
	F3	Untreated	Untreated
Four	A4	44-53	104-149
	C4	44-53	53-74
	D4	44-53	44-53
	E4	44-53	0-44
	F4	Untreated	Untreated

same time. The tests of Series One were run in the month of August, and were kept together in a room of fairly constant temperature. The tests of the other three series were run in October and kept in a greenhouse. The different climatic factors resulting from the differences in season and site of operation may have affected the final results of the experiments somewhat. Mortality counts were taken every twenty-four hours for a ninety-six hour period. Gross feeding estimates also were made at the twenty-four period to determine if the dusts had any effect on the rate of feeding. These were rated as none, slight, moderate and excessive damage (Fig. 6). The numerals 0, 1, 2 and 3 were used as working designations for these criteria, respectively, and the total average feeding per sample was expressed as a mean of the arithmetic sum of all the tests of a sample. The larger the numerical values the heavier was the feeding.

Observations were made on the coverage and adherence of each particle-size range, and some variation of these properties was found. The *Pyrax ABB* particles controlled the coverage and adherence, for they

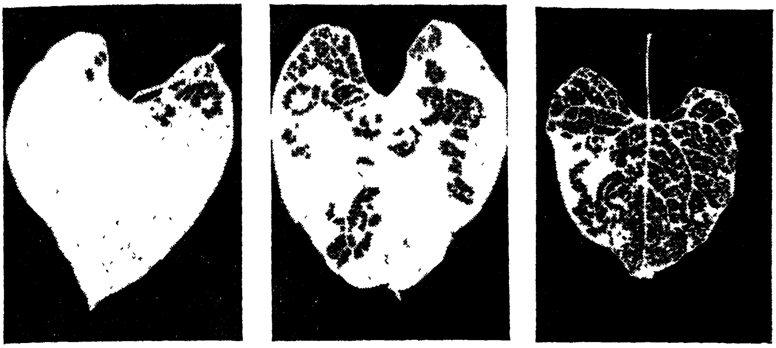

Fig. 6. Contact photographs showing slight, moderate and extensive feeding on bean leaves, referred to as (1), (2), and (3) degree damage.

comprised the bulk of any sample. A dust sample of the E1 size (0-44 microns), the smallest, gave the smoothest and the most consistent and best sticking coat on the bean leaves, as well as on the beetles. Dusts samples of the D1 size (44-53 microns), the next to the smallest, gave a coating that covered the foliage and beetles very well, though it did not adhere quite as well as did the smallest particle-size sample. Samples of the C1 size (53-74 microns) gave good coverage to foliage but only a fair coverage to the beetles, and did not stick very well to either. Samples of the B1 size (74-104 microns) gave a fairly consistent coverage to the foliage, but none to the beetles; and a slight jar would cause the material to fall from the foliage. The individual particles of the coating were discernible to the unaided eye at this size range. Samples of the A1 size (104-149 microns) gave a fairly consistent gross coverage, though very few of the particles would stick to the beetles. If a leaf dusted with this size particle was disturbed in any manner, the particles would fall. The individual particles of this size range were plainly discernible.

The data were reviewed statistically according to Love (5) and subjected to an analysis of variance to determine the reliability of the data. The least significant difference for mortalities between samples of a series were ascertained, also.

Results

Table III presents the average net mortality of bean beetles for the four dust samples in the first series of experiments. These samples were composed of combinations of diluent and toxicant of the same particle-size range and the untreated check.

These tests show that sample D1, representing a combination of the next to the smallest particle-size range, 44-53 microns, of toxicant and diluent was the best. Sample C1, representing a particle-size range of 53-74 microns, gave the next best mortality count, but the differences between C1 and D1 were not significant and cannot be accurately differentiated. The largest and smallest particle-size ranges, 104-149 and

TABLE III. The effect of particle size of a two per cent DDT dust in *Pyrax ABB*, of Series One, on the feeding and mortality of Mexican bean beetle adults.

Sample	Feeding Rate 24 Hours	Micron-size Range		Per Cent Mortality 72 Hours
		DDT	*Pyrax ABB*	
A1	2.0	104-149	104-149	41.6
C1	1.6	53-74	53-74	63.2
D1	1.5	44-53	44-53	76.8
E1	1.8	0-44	0-44	35.2
F1(Check)	2.8	.. -...	- .	1.6

Difference in mortality required for significance at odds of 99:1, 20.4

0-44 microns respectively, gave the least kills; the former gave a higher, but not a significantly higher, mortality count than the latter. Statistically the overall data were significant at odds of 99:1, and the difference made sample D1 significantly better than samples A1, E1 and the check, but not C1. Sample C1 also was significantly better than samples A1, E1 and the check. Samples A1 and E1 were only better than the check.

The sample in this test, D1, which caused the greatest mortality, also permitted the least feeding. Also the dusts of all the samples apparently had some repellency effect on the beetles, for more feeding was consistently done on the untreated checks than on any one of the four treated samples. The D1 size dusts gave good coverage and adherence, but not nearly as good as the E1 sample. This would indicate that particle-size has more effect on mortality than does coverage and adherence.

Table IV presents the average net mortality of bean beetles for the four dust samples in the second series of experiments. These samples were composed of the largest-sized DDT particles, 104-149 microns, in combination with all other *Pyrax ABB* particle-sizes except the 104-149 micron size, and the untreated check.

These showed that sample C2 representing a combination of the largest-sized DDT particles, 104-149 microns in combination with the middle-sized particle range of diluent, 53-74 microns, was the best. Sample D2, representing a combination of DDT and *Pyrax ABB* of micron-size ranges 104-149 and 44-53, respectively, was the next best. Sample B2, representing a combination of DDT and *Pyrax ABB* of micron size-ranges 104-149 and 74-104 respectively, was the next best. Sample E2, representing a combination of DDT and *Pyrax ABB* of micron size-ranges 104-149 and 0-44 respectively, gave the least kill. However, although statistically the overall data were significant at odds of better than 20:1, the difference in mortality required for significance at these odds was 18.5. At this value none of the mortalities for

TABLE IV. The effect of particle size of a two per cent DDT dust in *Pyrax ABB*, of Series Two, on the feeding and mortality of Mexican bean beetle adults.

Sample	Feeding Rate 24 Hours	Micron-size Range		Per Cent Mortality 72 Hours
		DDT	*Pyrax ABB*	
B2	2.0	104-149	74-104	27.2
C2	2.1	104-149	53-74	33.6
D2	2.2	104-149	44-53	28.8
E2	2.0	104-149	0-44	16.0
F2(Check)	2.6	- .	...-. .	4.0

Difference in mortality required for significance at odds of better than 20:1, 18.5

any of the samples were significantly better than any of the others and could not be positively differentiated. Sample E2 did not even show a significant mortality rate over that of the check, though all other samples of the series did.

The feeding rate among this series of treated tests was very consistent, all of the tests permitting about the same amount of feeding. The untreated check had a much higher feeding rate than any of the treated tests, and this indicates again that the dusts cause some repellency to the beetles. Since the least significant difference between mortalities, which was statistically computed, was greater than any of the differences between the actual mortality figures of any of the tests, it was not possible to draw significant conclusions concerning the effect of coverage and adherence to mortality as opposed to particle-size effect on mortality. But the indications are that particle size has more effect on mortality than does coverage and adherence, as was the case in Series One. Since the tests of Series One showed significantly that the particle size of DDT used as the toxicant of the dust sample in Series Two was one of the least desirable sizes, it might be anticipated that this DDT size would show up better tested with other particle-size ranges of the diluent. In other words, that the particle size of the diluent would have some effect in giving significant differentiations to mortalities. However, this was not the case, which would indicate that the particle size of the diluent does not have the pronounced effect on mortality that the particle size of the toxicant does, although there is some effect indicated.

Table V presents the average net mortality of bean beetles for the four dust samples in the third series of experiments. These samples were composed of the smallest particle-size range of DDT, 0-44 microns, in combination with all other *Pyrax ABB* particle sizes except the 0.44 micron size range, and the untreated check. The mortality data show that sample A3, representing a combination of the smallest-sized DDT particles, 0-44 microns, with the largest-sized particles of *Pyrax ABB*,

TABLE V. The effect of particle size of a two per cent DDT dust in *Pyrax ABB* of Series Three on the feeding and mortality of Mexican bean beetle adults.

Sample	Feeding Rate 24 Hours	Micron-size Range		Per Cent Mortality 72 Hours
		DDT	*Pyrax ABB*	
A3	2.1	0-44	104-149	12.8
B3	2.1	0-44	74-104	11.2
C3	2.1	0-44	53-74	8.8
D3	2.0	0-44	44-53	11.2
F3(Check)	2.3	- .	.. -	0.0

Difference in mortality required for significance at odds of better than 20:1, 8.2.

104-149 microns, was the best. Sample B3, representing a combination of DDT and *Pyrax ABB* of particle size ranges 0-44 and 74-104 microns respectively, was the next best sample. Sample D3, representing a combination of DDT and *Pyrax ABB* of particle-size ranges 0-44 and 44-53 microns respectively, produced the same kill as sample B3. Sample C3 representing a combination of DDT and *Pyrax ABB* of particle-size ranges 0-44 and 53-74 respectively, was the worst sample. However, the difference between the mortalities of any one of the samples was very small; and although the overall data were significant at odds of better than 20:1, the least significant difference of 8.2, which was computed statistically, between mortalities was greater than any of the differences between the actual mortality figures of any of the tests except the check. Therefore, it was not possible to draw significant conclusions concerning the effects on mortality of the various samples tested.

The feeding rate among this series of treated tests was almost identical in all cases; but the untreated check again permitted more feeding, indicating that the dust samples had some repellency effect on the beetles. As in the cases of Series Two, apparently the particle size of the diluent did not have the effect on mortality that the particle size of the toxicant had, because of the lack of significance between mortalities. It was not possible to draw significant conclusions concerning the individual effects of particle size and coverage in relation to mortality.

Another factor entered into this series of tests which makes all of the data recorded suspect despite the overall statistical significance. The DDT particles of this series were so small they tended to cling together and ball up on mixing. This caused lumps and an uneven distribution of the DDT throughout the diluent. This would cause a change in some of the constant factors of the tests, creating erroneous conclusions.

Table VI presents the average net mortality of bean beetles for the four dust samples in the fourth series of experiments. These samples were composed of a combination of the next to the smallest particle-size range of DDT, 44-53 microns, and the indicated particle-size ranges of *Pyrax ABB*, and the untreated check. The mortality data show that sample D4, representing a particle-size range of the next to the smallest, 44-53 microns, for both the DDT and the *Pyrax ABB*, was the best. Sample A4, representing a combination of DDT and *Pyrax ABB* of particle-size ranges 44-53 and 104-149 microns respectively, was the next best sample. Sample C4, consisting of DDT and *Pyrax ABB* of particle-size ranges 44-53 and 53-74 microns respectively, was the next best sample. Sample E4, consisting of DDT and *Pyrax ABB* of particle-size ranges 44-53 and 0-44 microns respectively, was the worst sample. However, although the overall data were significant at odds better than 20:1, the least significant difference of 15.2 required between mortalities was greater than the differences between the actual mortality figures of any of the samples. Therefore, it was not possible to draw significant conclusions concerning the effects of the various samples on mortalities, except in the case of the check. All of the samples except E4 were significantly better than the check. The feeding rate for all of the samples was very nearly the same; and as was the case in the other series of tests, the untreated checks allowed more feeding than did the treated ones. This indicates that the dusts had some repellency effect on the feeding of the beetles. Also, since there was no difference between the sample mortalities, it can be concluded from this series of tests as was concluded for Series Two and Three, that the particle size of the diluent does not have the effect on mortalities that the particle size of the toxicant does, although some effect is indicated. It was not possible to draw significant conclusions concerning the different effects of particle size and coverage in relation to mortality.

TABLE VI. The effect of particle size of a two per cent DDT dust in *Pyrax ABB* of Series Four on the feeding and mortality of Mexican bean beetle adults.

Sample	FeedingRate 24 Hours	Micron-size Range		Per Cent Mortality 72 Hours
		DDT	*Pyrax ABB*	
A4	1.8	44-53	104-149	20.0
C4	1.8	44-53	53-74	17.6
D4	1.8	44-53	44-53	27.2
E4	1.7	44-53	0-44	16.8
F4(Check)	2.5	-	-	2.0

Difference in mortality required for significance at odds better than 20:1, 15.2.

Conclusions

From the results obtained in these tests, the following conclusions may be drawn:

1. A two per cent dust sample composed of DDT of particle-size range 44-53 microns, in combination with *Pyrax ABB* of the same particle-size range, or a dust sample composed of the same materials each of a 53-74 micron particle-size range, was the most effective against adult Mexican bean beetle. In order of listing dusts composed of these same materials, each with respective particle-size ranges of 104-149 microns and 0-44 microns, were decreasingly effective in relation to the first two dust samples.

2. The coverage and adherence of any dust sample did not have the effect on mortality that the particle-size of the dust toxicant did.

3. The particle size of the DDT in a dust sample had more effect on mortality than did the particle size of the *Pyrax ABB,* although some effect by the latter was indicated.

4. The dusts had some repellency effect on the feeding of the bean beetles.

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Some Evolutionary Trends in Plecoptera[1]

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Structural Evolution

The families and subfamilies of stoneflies recognized by the writer are as follows:

	Distribution
A. Suborder Holognatha (Setipalpia)	
Eustheniidae	
Eustheniinae	Australia and New Zealand
Diamphipnoinae	Southern South America
Austroperlidae	Australia and New Zealand
Leptoperlidae	
Leptoperlinae	Australia and New Zealand; Fiji Islands; temperate South America
Scopurinae	Japan
Peltoperlidae	North and South America; east Asia and the bordering islands, south to Borneo
Nemouridae	
Notonemourinae	Australia and New Zealand
Nemourinae	Holarctic region
Leuctrinae	Holarctic region; South Africa; Tierra del Fuego
Capniinae	Holarctic
Taeniopteryginae	Holarctic
Pteronarcidae	North America; eastern Siberia
B. Suborder Systellognatha (Filipalpia)	
Perlodidae	
Isogeninae	Holarctic
Perlodinae	Holarctic
Isoperlinae	Holarctic
Chloroperlidae	
Paraperlinae	Nearctic
Chloroperlinae	Holarctic
Perlidae	
Perlinae	Old-world tropics, and the temperature regions of Africa, Eurasia and eastern North America
Acroneuriinae	North and South America; eastern and southeastern Asia

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[1] Contribution number 421 from the Department of Zoology, Indiana University.

Tillyard places the ancestors of present day stoneflies in the family Lemmatophoridae of the Permian order Protoperlaria. These insects had small wing-like lateral expansions of the prothorax, and a fairly well-developed posterior (concave) median vein in both wings, both of which have been lost in modern stoneflies. Developments in some of the morphological features which have been most studied are as follows:

Nymphal mouth parts: The holognathous families are characterized by bulky mandibles, by short thick palpi, and by having the paraglossae and glossae of the labium about equal in length. In the adult the mandibles remain large and functional. The systellognathous families have thin nymphal mandibles, more slender palpi, and paraglossae greatly exceeding the glosae. In the adult the mandibles commonly are much reduced, but Dr. Frison has described sclerotized mandibles in adult *Isoperla decepta* and *I. minuta*, and has observed the latter to feed.

Gills: Lateral abdominal gills are distinguishable in Protoperlaria and are a primitive character. Among modern families they occur regularly in Eustheniidae, where they are simple in Eustheniinae and branched in Diamphipnoinae. Other holognathous families lack lateral abdominal gills, but in many instances other gills have been developed. These are found in rather diverse locations; for example: on the 10th segment surrounding the anus (Leptoperlidae), inside the cloaca *(Leuctra claasseni)*, on the ventral side of the thorax and a few of the abdominal segments (Pteronarciidae), on the lateral and ventral sides of the thorax, and on the subanal lobes (Peltoperlidae), on the coxae *(Taeniopteryx)*, and even on the mentum *(Nemoura cataractae)*. Only one systellognathous stonefly has lateral abdominal gills *(Oroperla)*, but it also has a series of thoracic, cervical and submental gills whose homologues occur in varying abundance among other Isogeninae. Among the other subfamilies of Perlodidae all gills have been lost, except for short submental gills in some Perlodinae. Chloroperlidae lack gills entirely. Perlidae are all characterized by profusely branched lateral thoracic gills, and, in many species, by similar gills attached to the subanal lobes.

Cross-veins: A conspicuous evolutionary trend has been toward a reduction of crossveins. In Eustheniidae they are present almost throughout the wing; in Pteronarcidae most of the crossveins of the anal fan of the hind wing are gone, but they are profuse elsewhere; in Leptoperlidae and Austroperlidae they are less profuse but still numerous. Other holognathous groups have lost all or nearly all crossveins in the distal portion of both wings (except often in the costal space), and proximally retain only the mediocubital and intercubital series in the fore wings, and sometimes a fair series of costals. Even the M-Cu and Cu_1-Cu_2 series are much reduced in number in Capniinae. In Systellognatha two lines of descent start out with numerous crossveins but lose them in later development. Firstly, the isogenine perlids have few to many apical crossveins in *Arcynopteryx* and some *Isogenus*, but these are lost in the more advanced branches of *Isogenus* and in the derived Isoperlinae. Secondly, among the Perlodinae *Perlodes* retains apical crossveins but *Dictyopterygella* lacks them. They are likewise absent in Chloroperlidae.

Among the Perlidae, the Acroneuriinae often (but not always) have apical crossveins. Two genera *(Atoperla, Perlinella)* have retained (reacquired?) a few crossveins in the anal region of the forewing, but these lack any in the apical portions of the wings. The Perlinae typically lack extra apical crossveins, but one or two may appear sporadically. Finally, the hind wing has a series of intercubital crossveins in the primitive holognathous families, and also in Perlidae and most Perlodidae (reduced to 1-3 in *Isoperla*). In Nemouridae they are regularly reduced to a single crossvein, as is true also of Chloroperlinae and *Kathroperla,* but not of *Paraperla.*

Posterior portion of the wings: There has been a tendency for the anal area of the hind wing (and to a less extent the fore wing) to be reduced in more advanced forms, this reduction being correlated, in a general way, with small size of the insect as a whole. Thus among the holognathous families the small *Leuctrae* and *Capniae* have a small anal fold in the hind wing, while in *Capniella* the folded anal region is completely absent. The same development occurs in Chloroperlinae, where *Alloperla* has a rather small anal area, in *Chloroperla* it is much smaller with A_2 only about half as long as A_1, and in *Hastaperla* it is very small, with both anal veins vestigial. With the reduction of anal surface, the number of branches of the second anal vein of the hind wing of course also decreases. In Chloroperlinae the second cubital vein is much reduced in size in the fore wing, and the same is true even in the hind wing in *Hastaperla.*

Thoracic structure: The external anatomy of stoneflies has not been extensively studied from a comparative standpoint, an exception being Hanson's excellent monograph of Capniinae. However, the ventral thoracic plates have been used as a partial basis for generic or subgeneric recognition by Banks, Hanson and others. Here we will note only the "Y-ridge" or supporting structure of the mesosternum. I have not examined material of the primitive southern holognathous families, but such a ridge appears in Pteronarciidae and also in the Scopurinae of Japan. In both cases the arms of the ridge are attached to the posterior or inner corners of the furcal pits (elongate depressions marking the site of an inwardly-directed blade of the exoskeleton, used for muscle attachment). In primitive members of Isogeninae and also in all Perlodinae and Isoperlinae the same relationship holds; however in some members of both *Arcynopteryx* and *Isogenus* the arms of the Y become attached to the *anterior* corners of the furcal pits. This shift apparently occurred independently in the two genera, and there is considerable other variation in these and other ridges, particularly in *Isogenus.* Of the other systellognathous families, Chloroperlidae retain the primitive posterior attachment of the Y-ridge in some genera; in others the arms of the Y are lost. Perlidae have the anterior attachment, with the arms of the Y short and often nearly horizontal, more like a T.

Male genitalia: Nothing is more characteristic of stoneflies than the large supra-anal process which so often constitutes a main part of the male genitalial apparatus. It was already large and well developed in Protoperlaria, and occurs in much the same form in Eustheniidae, Leptoperlidae and Austroperlidae. In these forms the process is suspended from the tip of a strong, produced tenth tergite. The same point of insertion occurs in many Nemouridae, in particular Notonemourinae, most Capniinae, some Leuctrinae and some Nemourinae; however, except in Notonemourinae, the process is directed upward and/or forward, instead of downward. In other Nemourinae and most Taeniopteryginae the tenth tergite tends to be shortened, and weakened medially. In a few Leuctrinae and Capniinae the supra-anal process is lost, in which event the tergite remains (or again becomes) normally sclerotized.

Another line of development of the supra-anal apparatus consists of a shift of the attachment of the process forward to the front of the tenth tergite, splitting the tergite into two by the groove in which the process lies. At the same time a tough enveloping membrane or cowl is developed around the sides and posterior end of the process, which dorsally may become sclerotized to form the two paragenital plates. This is the condition found in the Pteronarciidae. The same arrangement occurs among the Isogeninae, with the addition of two lateral styles lying close to the supra-anal process, in most species. In the other two subfamilies of Perlodidae all this apparatus is lost, except that *Calliperla* (Isoperlinae) retains a small poorly-sclerotized process. The supra-anal apparatus still persists in Chloroperlidae: in the Paraperlinae it is fairly close to the typical isogenine form, except that no lateral stylets are present. In *Alloperla* all but the tip of the process is fused to the tenth tergite, in which case the tip is often referred to as the supra-anal process proper. In the subgenera *Sweltsa* and *Alloperla* s.s. there is still a deep groove in which the basal part of the apparatus lies. However, in *Suwallia* and *Neaviperla* this has largely disappeared. The same is true of the genera *Chloroperla* and *Hastaperla*, in some species of which it is difficult or impossible to differentiate the former basal part of the apparatus from the dorsum of the tergite, and only the small erect tip remains.

Finally, the Perlidae have all lost the accessory structures associated with the supra-anal process, but in the Perlinae the tenth tergite remains split and the genital hooks developed from its borders often assume complicated shapes. The process itself is a low, poorly sclerotized region merely filling in the back of the tergite. In Acroneuriinae the tenth tergite is complete posteriorly, though *Claassenia* has genital hooks developed from the sides of its posterior margin. The supra-anal process itself is unrecognizable except in the Japanese genus *Caroperla,* where it is terminal, erect and of moderate size—apparently a survival from pre-perlid ancestors.

The vagaries of the supra-anal process are of course often associated with a development or loss of other genitalial characters, of the most varied nature. No segment of the abdomen, unless it be the most anterior one, has escaped being involved in the male sexual apparatus, nor have its appendages the cerci and the subanal lobes. Many of these developments have little consistency from one genus to the next and have evidently been produced independently, hence are not of much value in tracing familial lineages; but others can be traced quite extensively and are mentioned in a later section.

Systematic List of Genera

The summary table to follow indicates the systematic position of the genera and subgenera to be currently recognized on the basis of the best information at hand. It is far from a definitive arrangement, as in many groups no recent revision has been attempted, and it seems that a considerable consolidation of genera should be effected, especially in Perlidae. In spite of this, the present arrangement should have some value when used in conjunction with Claassen's (1940) very useful world catalogue of Plecoptera. Because of Dr. Claassen's untimely death this catalogue did not receive the careful systematic reviewing which he had planned. The present generic list corrects at least the more obvious anomalies of the arrangement of the Catalogue, but errors doubtless remain, even though some of the more questionable genera have been listed by family only.

Apart from reassignment of a number of genera, the only novelties are the new subfamilies Diamphipnoinae (type genus *Diamphipnoa* Gerstaecker) and Notonemourinae (type *Notonemoura* Tillyard). It is possible that the large southern group Leptoperlinae could also conveniently be subdivided. On the other hand the subfamily Neoperlinae of Klapálek has here been consolidated with Perlinae. It was based solely on the absence of the anterior ocellus and the proximation of the posterior ones—characters found in members of various other groups where they have not evoked subfamilial recognition. It should be noticed that although numerous species of *Neoperla* have been described from the American tropical regions, none has been shown to have genital hooks developed from the tenth tergite, and it is to be presumed that they all belong in *Anacroneuria* or some related genus. No unquestioned Perlinae have been taken, in America, south of the United States.

- Family Eustheniidae Tillyard 1921
  - Subfamily Eustheniinae
    - *Eusthenia* Westwood 1832
    - *Eustheniopsis* Tillyard 1921
    - *Stenoperla* MacLachlan 1866
    - *Thaumatoperla* Tillyard 1921
  - Subfamily *Diamphipnoinae* new
    - *Diamphipnoa* Gerstaecker 1873
- Family Austroperlidae Tillyard 1921
    - *Austroperla* Needham 1905
    - *Tasmanoperla* Tillyard 1921
- Family Leptoperlidae Tillyard 1921
  - Subfamily Leptoperlinae
    - *Antarctoperla* Enderlein 1905
    - *Auklandobius* Enderlein 1909

Dinotoperla Tillyard 1921
Eunotoperla Tillyard 1924
Gripoptera Sámal 1921
Gripopteryx Pictet 1841
Klapopteryx Pictet 1841
Leptoperla Newman 1839
Megaleptoperla Tillyard 1923
Nesoperla Tillyard 1923
Nydyse Navás 1923
Paragripopteryx Enderlein 1909
Paranotoperla Enderlein 1909
Senzilla Navás 1917
Trinotoperla Tillyard 1924
Zelandobius Tillyard 1924
Zelandoperla Tillyard 1923
Subfamily Scopurinae Uéno 1938
Scopura Uéno 1929

Family Peltoperlidae Claassen 1931
Cryptoperla Needham 1909
Neopeltoperla Kohno 1945
Nogiperla Okamoto 1912
Peltoperla Needham 1905
Incertae sedis, possibly Peltoperlidae: *Microperla* Chu 1928, *Styloperla* Wu 1935

Family Nemouridae Klapálek 1905
Subfamily Notonemourinae new
Notonemoura Tillyard 1923
Spaniocerca Tillyard 1923
Spaniocercoides Kimmins 1938
Subfamily Nemourinae Klapálek 1905
Nemoura Pictet 1841. Subgenera *Amphinemura* Ris 1902, *Nemurella* Kempny 1898, *Paranemoura* Needham and Claassen 1925, *Protonemura* Kempny 1898.
Subfamily Leuctrinae Klapálek 1905
Aphanicerca Tillyard 1931. Subgenera *Aphanicercella* Tillyard 1931, *Aphanicercopsis* Barnard 1934.
Desmonemoura Tillyard 1931
Leuctra Stephens 1835. Subgenera *Despaxia* Ricker 1943, *Moselia* Ricker 1943, *Pachyleuctra* Despax 1929, *Paraleuctra* Hanson 1941.
Megaleuctra Neave 1934
Perlomyia Banks 1906
Rhopalopsole Klapálek 1903
Strobliella Klapálek 1903
Udamocercia Enderlein 1909
Subfamily Capniinae Klapálek 1905
Allocapnia Claassen 1928
Apteroperla Matsumura 1931

    - *Capnia* Pictet 1941. Subgenus *Parcapnia* Hanson 1946
    - *Capniella* Klapálek 1920
    - *Capnioneura* Ris 1905
    - *Capnopsis* Morton 1896
    - *Eucapnopsis* Okamoto 1922
    - *Isocapnia* Banks 1938
    - *Nemocapnia* Banks 1938
    - *Takagripopteryx* Okamoto 1922
  - Subfamily Taeniopteryginae Klapálek 1905
    - *Brachyptera* Newport 1848. Subgenera *Doddsia* Needham and Claassen 1925, *Obipteryx* Okamoto 1922, *Oemopteryx* Klapálek 1902, *Rhabdiopteryx* Klapálek 1902, *Strophopteryx* Frison 1929, *Taenionema Banks* 1905.
    - *Kyphopteryx* Kimmins 1946
    - *Taeniopteryx* Pictet 1841
  - Nemouridae of uncertain affinity: *Allonuria* Claassen 1936, *Napcia* Navás 1917, *Neofulla* Claassen 1936, *Neonemura* Navás 1919, *Nephopteryx* Navás 1915.
- Family Pteronarcidae Enderlein 1909
    - *Pteronarcella* Banks 1900
    - *Pteronarcys* Newman 1838
- Family Perlodidae Klapálek 1912
  - Subfamily Isogeninae Ricker 1943
    - *Arcynopteryx* Klapálek 1904. Subgenera *Filchneria* Klapálek 1907, *Frisonia* Ricker 1943, *Megarcys* Klapálek 1912, *Oroperla* Needham 1933, *Perlinodes* Needham and Claassen 1925, *Protarcys* Klapálek 1912, *Skwala* Ricker 1943.
    - *Isogenus* Newman 1833. Subgenera *Dictyogenus* Klapálek 1904, *Diploperla* Needham and Claassen 1925, *Hydroperla* Frison 1935, *Isogenoides* Klapálek 1912, *Pictetia* Banks 1947.
    - *Pseudomegarcys* Kohno 1946
  - Subfamily Perlodinae
    - *Dictyopterygella* Klapálek 1904
    - *Perlodes* Banks 1903
    - *Perlodinella* Klapálek 1912
    - *Skobeleva* Klapálek 1912
  - Subfamily Isoperlinae Frison 1942
    - *Calliperla* Banks 1947
    - *Isoperla* Banks 1906
  - Perlodidae of uncertain position: *Diperla* Návas 1936, *Hedinia* Navás 1936, *Suzukia* Okamoto 1912.
- Family Chloroperlidae Okamoto 1912
  - Subfamily Paraperlinae Ricker 1943
    - *Kathroperla* Banks 1920
    - *Paraperla* Banks 1906
  - Subfamily Chloroperlinae
    - *Alloperla* Banks 1906
    - *Chloroperla* Newman 1836

Haploperla Navás 1934
Hastaperla Ricker 1935

Family Perlidae
Subfamily Acroneuriinae Klapálek 1914
Acroneuria Pictet 1941. Subgenera *Beloneuria* Needham and Claassen 1925, *Eccoptura* Klapálek 1921, *Hesperoperla* Banks 1938, *Niponiella* Klapálek 1907.
Anacroneuria Klapálek 1909
Atoperla Banks 1905
Brahmana Klapálek 1914
Caroperla Kohno 1946
Claassenia Wu 1934
Eutactophlebia Klapálek 1914
Gibosia Okamoto 1912
Inconeuria Klapálek 1916
Kalidasia Klapálek 1914
Kempnyia Klapálek 1914
Kiotina Klapálek 1909
Klapalekia Claassen 1936
Macrogynoplax Enderlein 1909
Mesoperla Klapálek 1913
Mesoperlina Klapálek 1921
Neoeuryplax Claassen 1936
Nirvania Klapálek 1914
Onychoplax Klapálek 1914
Perlesta Banks 1906
Perlinella Banks 1900
Schistoperla Banks 1937
Subfamily Perlinae McLachlan 1886
Agnetina Klapálek 1907
Cerconychia Klapálek 1913
Dyaperla Banks 1939
Etrocorema Klapálek 1909
Formosita Klapálek 1914
Hemimelanena Klapálek 1907
Kamimuria Klapálek 1907
Kiotina Klapálek 1907
Marthamea Klapálek 1907
Neoperla Needham 1905. Subgenera: *Javanita* Klapálek 1909, *Ochthopetina* Enderlein 1909, *Oodeia* Klapálek 1921, *Phanoperla* Banks 1938.
Neoperlops Banks 1939
Neophasganophora Lestage 1922
Oyamia Klapálek 1907
Paragnetina Klapálek 1907
Perla Geoffroy 1764. Subgenera: *Dinocras* Klapálek 1907, *Esera* Navás 1909.
Tetropina Klapálek 1909

Togoperla Klapálek 1907
Tylopyge Klapálek 1913

Perlidae of uncertain affinities: *Collampla* Navás 1929, *Colloperla* Navás 1936, *Folga* Navás 1918, *Forca* Navás 1925, *Forquilla* Navás 1924, *Laeissa* Navás 1934, *Nakaharia* Navás 1916, *Nedanta* Navás 1932.

Distribution of the Families and Subfamilies

On zoogeographical grounds various groups of stoneflies can be arranged as follows:

1. Eustheniidae, Leptoperlidae and Austroperlidae are ancient families now confined to the southern periphery of a probable former world-wide range—namely the Australasian region and southern South America—thus paralleling the well-known distribution of the marsupials among mammals. However a wingless leptoperlid has persisted in Japan.

2. The Pteronarciidae are to be regarded as a North American family, primarily, which has invaded Asia in relatively recent times, where it is known from eastern Siberia and Sakhalin.

3. Peltoperlidae are rather generally distributed in North America, but are not rich in species. A single species has been described from South America, but it is poorly known. In Asia the family is represented from Japan and the China coast southwestward to India, and on adjacent islands of the Pacific; but again is nowhere abundant.

4. The nemourid holognathous stoneflies are represented by a distinct subfamily in Australasia, and by some Leuctrinae in South Africa and in Tierra del Fuego *(Udamocercia)*. Like the Eustheniidae *et al.*, these southern forms can be regarded as survivals of types once much more widespread. In the case of *Udamocercia*, the closely-related (?identical) genus *Megaleuctra* still lives in North America, and has also been recognized in the Baltic amber. The more typical Leuctrinae, and also the Nemourinae, Capniinae and Taeniopteryginae have a holarctic distribution, south in Asia to the Himalayan ranges and in America to Mexico City *(Nemoura venusta)*.

5. Among Systellognatha two of the families are holarctic while the Perlidae are primarily tropical. Both in Perlodidae and Chloroperlidae the North American fauna seems more varied than the Eurasian—though it is also better known. In any event more interesting primitive forms or "missing links" have turned up in America—for example *Oroperla*, *Calliperla* and the Paraperlinae—but it is scarcely possible to identify the center of origin of either family.

6. The Perlidae divide themselves rather sharply into the two subfamilies Perlinae and Acroneuriinae, characterizing the old and new worlds respectively. Most abundant in the American tropics, Acroneuriinae also have a considerable development in temperate North America. They are fairly numerous in eastern Siberia, Japan and China and also occur in India *(Brahmana)* and the Malayan region *(Kalidasia)*, if these two genera are true acroneuriines.

The Perlinae, on the other hand, are *the* stoneflies of the old-world tropics, including Africa, India and the East Indies. A fair number of species range north into Europe, and a much larger number occur through central Asia, China and Japan. Three Oriental genera have invaded North America, presumably not too long ago. These are *Neoperla* (1 species), *Neophasganophora* (1 or 2 species) and *Paragnetina* (5 species). However, it is interesting that none of these species occurs west of the great plains, where they might have been expected to be if the invasion has been really recent.

Evolutionary Sequence

No study of this sort is complete without a family tree, even if only a tentative one. Like most phylogenetic trees, the one shown in figure 1 is simplified in this respect: that, strictly speaking, no living group of organisms is the ancestor of any other living group. This is true even in cases (which are known at the specific and possibly the generic level in some well-studied groups of animals) where a given form X seems likely to have given birth to form Y, and X appears not to have changed appreciably itself since the event. When dealing, as here, with families and subfamilies, such an eventuality becomes most improbable. For example, no modern isogenine is ancestor to any other stonefly family or subfamily; we suggest only that some modern Isogeninae are reasonable facsimilies of the real ancestors of Chloroperlidae, etc., and can stand for them in the family tree. Or in other words, if the actual ancestors were before us, we believe that they would look enough like modern isogenines to be classified in the same subfamily. In figure 1 groups having combinations of characteristics not present in any known species are shown in boxes and are given a letter designation.

The transition from the Permian Protoperlaria to modern stoneflies was marked by the loss of the lateral expansions of the prothorax and the loss of the posterior median vein. The Eustheniinae are possible ancestors of all other living stoneflies. The transition from Eustheniinae to Leptoperlidae was a simplification of venation, loss of lateral gills, and a development of circumanal branched gills.

Concerning the origin of Nemouridae there are two possible hypotheses, between which it is difficult to choose. Taking a leptoperlid as a starting point, a further loss of crossveins and loss of the circumanal gills would yield a primitive nemourid (C). Such a nemourid would have retained long cerci and would have copulatory apparatus somewhat as in Notonemourinae, where the suspension of the supra-anal process and subanal lobes are much akin to some forms of Leptoperlidae, with the exception of the ventral lobe on the ninth sternite—the latter being a very characteristic nemourid structure. It is this lobe, however, which suggests a relationship between Nemouridae and Peltoperlidae, which also have it, and in that event these two families would have branched directly from Eustheniidae and had a short common history before going their separate ways. This is the path illustrated in figure 1. Whatever their origin, a major cleavage soon occurred among the early nemourids,

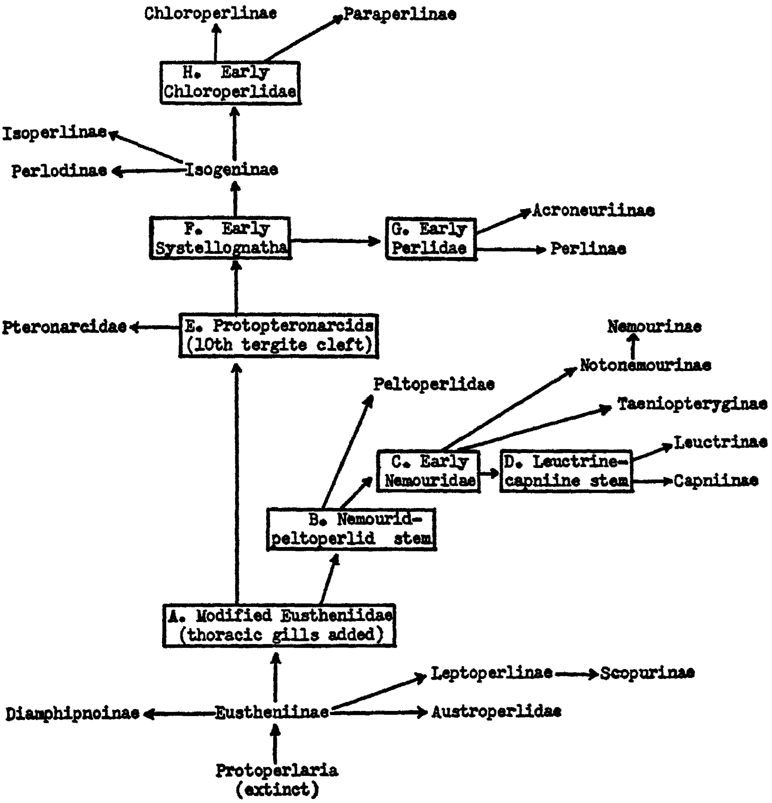

Figure 1. Tentative phylogenetic tree for Plecoptera.

splitting off a group (D), characterized by slender nymphs having wing pads lying parallel to the axis of the body, from the more robust nymphal types having the wing pads set obliquely (the primitive position). Group D became further divided into the modern Capniinae and Leuctrinae, of which the former characteristically have reduced medial and cubital crossveins and long cerci, and the latter have several crossveins and only a single cercal segment—though it is not easy to draw a satisfactory line of demarcation. The more typical nemourine stem gave rise to the Taeniopteryginae on the one hand and the Notonemourinae on the other, the latter being an Australasian subfamily some of whose members are quite plausible ancestors of the widespread northern Nemourinae.

The Peltoperlidae are the most puzzling of stoneflies. Their body form superficially suggests a cockroach, and it is perhaps surprising that they have not at some time or other been considered as direct descendants of some palaeozoic blattoid ancestor! Venation and gills, of course, would not permit such a phylogeny even if a suitable ancestor were available. The thin posterior projections of their nymphal thoracic sterna are apparently unique in the order. The ventral lobe of Peltoperlidae suggests nemourid affinities, while their thoracic gills relate them to the main stem of stonefly evolution. The latter occurrence makes it necessary to place the origin of double thoracic gills far back in the history of the group—probably in a form still recognizable as a eustheniid (A). Such an ancestor also had a pair of cervical gills (found in two surviving isogenines and a few *Peltoperlae*) and possibly also the submental gills characteristic of many isogenines. The supra-anal process of *Peltoperla* is not as prominent as in Eustheniidae or Nemouridae, but the tenth tergite has not been cleft.

The main trunk of stonefly evolution from the Eustheniidae apparently led first to a form (E) in which the tenth tergite became split and the suspension of the supra-anal process moved forward to the segment's anterior border; it probably also had lost some of the crossveins of the anal area of the hind wing. Of such a form the Pteronarcidae are the nearest modern representatives, differing only in the fact that the gills have shifted to a ventral position, have become branched, and, on the abdomen, are gone from all but the two or three most anterior segments. Further "main-line" evolution of Group E involved a major change in nymphal mouth parts from the holognathous to the systellognathous type, corresponding, in general, to a change in feeding habit from herbivorous to carnivorous. The ancestor which made this change (F) still had the lateral abdominal and thoracic gills, and had a fairly profuse supply of crossveins. Both of these characters persist in the more primitive Isogeninae, though abdominal gills occur in only one species today. Evolution within the Isogeninae involves a progressive loss of gills and of crossveins; while the loss of the supra-anal apparatus, on two separate occasions, has produced the Isoperlinae and Perlodinae. A third development from Isogeninae yielded the Chloroperlidae, which retained the supra-anal process. This family is characterized by long slender nymphs usually with short cerci, and with mouth parts somewhat altered from the perlodid form. Surviving genera also have either an unusually elongated head capsule (Paraperlinae), or the anal area much reduced in the hand wing and the second cubital of the forewing very short (Chloroperlinae); but they were doubtless preceded by early forms (H) which lacked these specializations.

Most characteristic of all modern stoneflies are the Perlidae—the only family which has been really successful in adapting itself to tropical conditions; or perhaps we should say, which has driven other families out of the lush tropical zone. Our figure shows it diverging from the primitive systellognathous ancestor (F) which it had in common with the Perlodidae. The abdominal gills of that ancestor do not appear in any modern perlid, but its lateral thoracic gills are a constant feature of the family—they are always finely branched however.

At an early stage the family divided into the two groups which today are characteristic of the two hemispheres. In both divisions the supra-anal process lost all function or disappeared (except that one acroneuriine, *Caroperla,* still has it, quite possibly from primitive times). In Perlinae the "genital hooks", or elongated corners of the cleft of the tergite, are retained and indeed undergo a rather grandiose development, taking complex forms in different genera. At the same time the surplus crossveins of the wing have disappeared. The Acroneuriinae, on the other hand, have lost the genital hooks of the tenth tergite, which latter has become entire (except for hooks developed more laterally in *Claassenia*); however the subanal lobes are almost always produced upward into sharp hooks or similar copulatory organs. Many *Acroneuriae* also retain the numerous apical crossveins which must have characterized the earliest Perlidae.

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Studies on the Control of the *Taxus* Mealybug

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Agricultural Experiment Station

The Taxus mealybug which occurs over the entire State, is a serious pest of Taxus in the nursery. Although its identity is still controversial, the insect is probably a grape mealybug *Pseudococcus maritimus* (Ehrh.). In connection with our work on this insect in Indiana (1949) we found small nymphs, barely discernible with the naked eye, at Weigand's Evergreen Nursery, Indianapolis, Indiana on April 12. It is reported that the insect overwinters as a small nymph protected by the white waxy threads produced by the female as well as by bits of bark, dead foliage and other debris. By May 17 the mealybugs were established on the twigs where they feed. By June 22 adult mealybugs, egg masses and small nymphs were present in abundance.

Until R. B. Neiswander (1949, Jour. Econ. Ent. 42(1):41-44) discovered the effectiveness of parathion applied as two sprays in the middle of May and the first of June no 100 percent control measure was known.

In 1949 six materials and one mixture were tested on two varieties of Taxus commonly grown in the nursery, *Taxus cuspidata* and *T. cuspidata* var. *capitata*. Each of the five materials were applied to a ten shrub plot at the Weigand's Evergreen Nursery. The plots were arranged in a randomized block design and replicated four times. The first application was made on May 17 and the second on June 7. The mixture of parathion and the miticide C-854 was applied only once on May 17. These materials were applied at 200 pounds pressure with a *Spartan Sprayer*, model 3, equipped with a *Tee Jet* nozzle No. SS 8006.

Fifteen days after the last application twig samples, approximately 6 inches long, were taken from the approximate middle of each plant. The twigs were placed in waxed ice cream cartons and returned to the laboratory where the branches were examined under the microscope and the mealybugs and egg masses counted.

It was noted from these data, presented in Table I, that two applications of parathion gave complete control, while one application of the mixture of parathion and the miticide C-854 gave almost perfect control since only one adult and no egg masses were found in the samples. It will also be noted that the variety *T. cuspidata capitata* which is a more dense shrub had more mealybugs and egg masses than the more open *T. cuspidata.*

TABLE I. Effect of various chemicals on the mealybug.

Material and dilution per 100 gallons	Manufacturer	*Taxus cuspidata*		*Taxus cuspidata* var. *capitata*	
		No. Live Mealy-bugs	No. Egg Masses	No. Live Mealy-bugs	No. Egg Masses
Parathion, 1 pound (25%)	American Cyanamid Company	0	0	.	.
Mixture, parathion 1 pound (25%) and C-854,[1] 1 pound (50%)				1	0
C-854,[1] 1 pound (50%)	Dow Chemical Company	13	2	18	8
methoxychlor, 2 pounds (50%)	E. I. du Pont de Nemours and Company, Inc.	43	4	33	14
Compound 118[2] 1 pound (25%)	Julius Hyman and Company	5	2	25	13
Compound 497,[3] 1 pound (25%)	Julius Hyman and Company	6	4	27	14
TDE (DDD) 2 pounds (50%)	Rohm and Haas Company	36	6	24	15
Check-untreated		27	2	29	17

[1] A miticide containing 50% of K-6451 (p-chlorophenyl p-chlorobenzenesulfonate).

[2] Compound 118 has the chemical formula 1,2,3,4,10,10-hexachloro-1:4,5:8 diendomethano-1,4,4a,5,8,8a-hexahydronaphthalene.

[3] Compound 497 has the chemical formula 1,2,3,4,10,10-hexachloro-6, 7-epoxy-1,4,4a,5,6,7,8,8a-octahydro-1,4,5,8-dimethanonaphthalene.

GEOLOGY AND GEOGRAPHY

Chairman: PRESTON MCGRAIN, Indiana Flood Control
and Water Commission

O. P. Starkey, Indiana University, was elected chairman for 1950.

ABSTRACTS

Topographic Mapping in Indiana. C. H. BECHERT, Division of Water Resources, Indiana Department of Conservation.—The first topographic maps of quadrangles in Indiana were issued early in the 1900's. They were of areas in the southwestern part of the State, that section being selected because of the coal deposits. The scale was 1 to 62,500. About 20 maps of this type were published of areas wholly or in part within Indiana. The later maps are on a scale of 1 to 24,000, comprise about 57 square miles each and have 20 or 10-foot contours except in a few areas where 5-foot contours are used. Within the last few years more uniform progress is being made in the mapping program and to date approximately a fourth of the state has been mapped. This has been accomplished by an annual appropriation by the State Legislature of $50,000 which amount is matched by Federal funds. The maps are obtainable from the Division of Water Resources and as many as 300 have been distributed in one month. They are used extensively by oil and gas operators, water well drillers, coal producers, contractors, utilities, and sportsmen.

Florida Pebble Phosphate. ARTHUR B. CARR, Indianapolis.—Sketch of the geologic origin of the great Land Pebble Phosphate of Lime deposits of Florida, which state is producing three fourths of the nation's output of fertilizer, with conservatively estimated six billion tons of ore in sight, and an unbelievable reserve, sufficient at present production to last eight thousand years.

A dramatic picture of a vast, ancient land and marine animal life in Florida, the phosphatized bones of which are daily being taken from the mines.

Also, very briefly, the story of the intricate process employed by ten great plants in one area, in converting the mined pebbles into soluble plant-food for world consumption, the yearly output of one mine alone being one and a half million tons.

"The world must be fed, and phosphate fertilizer seems the answer, if wasted lands are to be restored, that world peoples are to survive."

Secondary Recovery by Water Pressure in the Casey (Illinois) Oil Field. ROBERT R. DRUMMOND and LAMONT DEHL, Indiana State Teachers College.—For some years various experimental processes of secondary recovery of crude oil have been carried on by a number of companies. This paper concerns itself with a very successful operation in a "nearly exhausted" field located near Casey, Illinois.

Late in 1946 the Forest Oil Company of Pennsylvania began an attempt to adapt methods found successful in Pennsylvania to the old Casey Pool. Earlier attempts at pressurizing with air had proved only moderately successful and were, subsequently, abandoned. The new operation began the first local use of water pressurizing with the "Five Spot" method.

Success over the last two years has truly been spectacular and, as a result, an old field has taken on a new lease on life.

The Ohio Oil Company has watched this small operation with more than usual interest and much portends for this successful method.

Collecting and Utilizing Water Well Records. T. M. KINGSBURY, Division of Water Resources, Indiana Department of Conservation.—About three years ago the Division of Water Resources solicited the members of the Indiana Water Well Drillers Assn. at its annual meeting to cooperate in the collection of ground water information in Indiana by supplying well records, pumping tests, water level measurements and other pertinent data. It was explained that the purpose was to learn more about the State's ground water resources, the areas and formations which were water bearing, the quantities of water that were available, etc. To promote this project the Division published pocket-sized booklets containing about 100 well record forms in alternate white and yellow sheets. These were distributed among drillers who were asked to return the well records on the white sheets and keep the yellow sheets in the book for their own use. Last year the Division collected more than 1200 well records through voluntary cooperation. There are no state laws, as in the case of oil or gas wells, requiring drillers to furnish the Department with logs of wells. These logs have added materially to the fund of information on subsurface conditions, with emphasis on one of our most important resources—water. From them more is being learned about thickness of glacial drift in areas not drilled for oil or gas and about preglacial erosion.

A Giant Earth Mover. G. DAVID KOCH, Indiana State Teachers College.—At their Chieftain Mine, No. 20, about four miles south of Riley, Indiana, Maumee Colleries have in operation one of the largest draglines in the world. This huge earth mover has a boom 215 feet long and swings a bucket with a 25 cubic yard capacity. The boom, which extends into space at a 42 degree angle, can dig 120 feet below ground level and dump earth about 60 feet above that level.

The dragline is used exclusively for removing an overburden that averages 57 feet, 7 inches thick and consists of clay, gravelly clay, limestone and slate. The coal seam, which is being exposed, averages 5 feet, 1 inch in thickness.

The Swallow-holes of Lost River, Orange County, Indiana. CLYDE A. MALOTT, Indiana University.—Approximately 45 square miles of the area of the upper part of the Lost River system has a normal surface drainage down a gentle westerly sloping limestone upland. The gathered stream waters from this area discharge onto a sinkhole plain and are absorbed in numerous small and several large swallow-holes developed in and near the stream channel. The underground stream formed by these sinking waters runs through cavernous routes for a distance of 8 miles, while a surface dry-bed channel, only infrequently flooded by excessive stormwaters, meanders about on its way across the sinkhole plain for a distance greater than 20 miles. The dry-bed with its swallow-holes in its upper section and its resurgences at its lower end is mapped and its features described in some detail. Special attention is given to the large Tolliver swallow-hole which may be entered and its route followed to underground Lost River which here is 75 to 80 feet below the upland sinkhole plain.

The development of the extensive sinkhole plain and the swallow-holes in the dry-bed channel has been dependent upon a lowering of the watertable below the level of the upland and the dry-bed channel. Upstream from the dry-bed on the same upland limestone plain the watertable is close beneath the surface and the stream beds which form the headwater section of Lost River. Little or no subterranean drainage is developed throughout the 45 square miles of the area. In the region of the sinkholes and the swallow-holes of the dry-bed the watertable has withdrawn far below the upland plain and the river channel, and the surface and stream waters go below and form a great underground drainage system. In the lower section of the dry-bed channel and at its terminus the valley of Lost River is deeply intrenched and its channel approaches and reaches the watertable. Here the resurgences occur and normal surface drainage is restored.

Preliminary Report on the Thickness of Glacial Drift in the Upper Wabash Drainage Basin. PRESTON MCGRAIN, Indiana Flood Control and Water Resources Commission.[1]—Great variations in thicknesses of glacial drift have been noted in the upper Wabash Basin area. These variations are due to a large extent to the presence of a former major drainage system which is now buried and hidden from view. The presence of morainic masses and the depth of stream dissection are other important factors affecting the variability in thickness. Thicknesses from nothing to more than 450 feet have been encountered.

This study was a part of flood control investigations and surveys along the upper Wabash River and its major tributaries. It was prompted by the need of determining the strength, stability, porosity, and permeability of the earth materials at possible dam sites, the effectiveness and water-tightness of resulting reservoirs, and the geological conditions in the watershed areas. This geological survey covered parts of 26 counties. In addition to personal observations the logs of more than 3500 wells were collected and studied. These records are on file in the offices of the Indiana Flood Control and Water Resources Commission in Indianapolis.

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[1] Published by permission of the Chief Engineer, Indiana Flood Control and Water Resources Commission.

The trunk stream of the buried drainage system is the Teays (Kanawha). The valley of this stream occupied a sinuous course across Adams, Jay, Blackford, Grant, Wabash, Miami, Cass, White, Carroll, Tippecanoe, Warren, and Benton counties in Indiana. Other buried valleys which were tributaries to the Teays (Kanawha) were located. Some of the latter can be traced for tens of miles. Tributary valleys are noticeably more narrow than the main valley.

Nearly flat or gently rolling limestone uplands characterize most of the inter-valley areas. Pennsylvanian and Mississippian sandstones, and Mississippian and Devonian shales cap the bedrock sequence in the western part of the area studied.

A variety of materials fill the buried channels. However, it may be said that where the former stream flows in a southerly direction coarse sands and gravels are generally present in quantities. Where north flowing, the valleys are generally filled with fine-grained sediments.

Character of Sand in the Ohio River Formation, JOHN B. PATTON, Division of Geology, Indiana Department of Conservation.—The Ohio River formation (Tertiary, Pliocene?) occurs in Clark, Floyd, Washington, and Harrison counties, Indiana, and is composed of poorly consolidated sandstone and conglomerate. Sand from the formation was formerly used for manufacturing glass, and a little is still used in finishing plaster. An increasing interest in sources of high-silica material accentuates the need for quantitative information on all such deposits. Chemical, spectrographic, and sieve analyses of samples from the most recently opened pit in the Ohio River formation are presented.

Regional Influences upon the Canadian Railway Pattern, WILLERT RHYNSBURGER, Indiana University.—The railways of Canada, in contrast to the situation in the United States, are of pre-eminent significance to the national economy. This paper briefly examines the patterns of railway routes in the settled part of Canada in terms of the major physiographic realms. A threefold classification of regional transport functions is suggested: (1) the drawing-off of the commodities of primary surplus production; (2) the carriage of goods over long distances of unproductive territory; (3) the assembling and interchange of goods at the great manufacturing and marketing centers.

In the Cordillera and on the Shield, each with only about 3 miles of line per 100 square miles of area, the railways perform primarily a transit function. In the Prairie Provinces and in the Maritimes, with about 7 miles of line per 100 square miles, the drawing-off of surplus production is the principal railway function. In the metropolitan region of Canada, the St. Lawrence Lowland, which has almost 15 miles of railway line per 100 square miles, the terminal function equals in importance the moving of surplus production.

Some Geographic Recreational Aspects of Unglaciated Indiana

THOMAS FRANK BARTON, Indiana University

Because of the great abundance and diversity of landforms, water bodies, vegetation, historical landmarks, and land well adapted to recreational advantages, Indiana's southland has a great potential in recreation. By re-evaluating the recreational opportunities, advertising their advantages, and providing adequate facilities, the recreation-travel industry of this area could offer wholesome outdoor recreation for thousands dwelling in nearby cities and at the same time bring economic returns and prestige to an area not well adapted to mechanical cultivation.

For decades the counties in the unglaciated hill lands were relatively isolated. For nearly a half century now, highly mechanized methods of cultivation, well adjusted to level land, have avoided our hills. Also during this same period, we have been largely by-passed by the great streams of rail or waterborne freight and traffic moving back and forth between the eastern and western, the northern and southern parts of our country. Even secondary streams of freight and traffic moving back and forth from Indianapolis to Evansville on the west or between Indianapolis and Louisville, Kentucky, on the east skirted the rugged southern Indiana hills.

During the same decades, especially to the north but also to the south, a highly mechanized form of industrial life mushroomed hamlets into villages, villages into cities, and cities into metropolises. Today, millions of urban dwellers are seeking outdoor recreation.

From the standpoint of modern recreational needs, now is an opportune time to re-evaluate the resources of unglaciated Indiana and make an inventory of our assets better known to the public. Such an evaluation will not only show many assets, but it will also point out a few deficiencies which need to be corrected.

Geographic Recreational Assets

What are some of the geographic recreational assets of the area?

1. *Strategic geographic location.* Situated in the heart of the Ohio Valley, the unglaciated hill country is strategically located to serve millions of people. Many of the principal tourist lanes leading from north to the winter vacation lands of the Gulf States and Mexico, or from south to the summer resorts in the Lake States and Canada pass through southern Indiana.

Ideally, the greatest tourist migrations from north to south and south to north take place in fall and spring—the seasons when people find Indiana's southland most colorful. The area is highlighted by a rich year-around schedule of recreational and cultural activities on the Indiana University campus, the Indianapolis automobile races, and the Kentucky derby at Louisville.

From the standpoint of our national population, these hill lands are centrally located. The center of population in the United States has been in or near this region for six decades, 1890-1940. Bloomington, the northern gateway to scenic southern Indiana, was the center of population in the United States in 1910.

In contrast with the seasonal vacation travel enjoyed by thousands are the week, weekend, or day (Sunday and holidays) type of recreation. All the cities in Illinois, Indiana, Ohio, Kentucky, and Tennessee are within one day's driving distance from this region.

This area is also accessible to several million people who live within a few hours' drive and who want to relax outdoors for a few hours or days in the spring, summer, and fall. Mitchell is near the center of this unglaciated area. Within a hundred mile radius of this city, some of the largest cities are Cincinnati, Indianapolis, Louisville, Terre Haute, Evansville, and Owensboro. These six cities alone have a total population of nearly one and one-half million.

2. *Rugged and varied topography.* A rugged and varied topography is considered an important recreational asset. Our state's most irregular terrain is found here. The three most rugged Indiana counties, Perry, Crawford, and Brown, are in this area. We also have a great variety of landforms with recreational value. There are weirdly sculptured rocks such as the Pinnacle and Jug Rock near Shoals. There are picturesque bluffs, escarpments and ridges such as McBride's Bluff, Knobstone escarpment and Kin Hubbard Ridge. There are numerous steep cliffed-lined youthful valleys. There are many nearly inaccessible and isolated depressions, ravines, and valleys such as Possum Valley and Cave River Valley. Scenic views such as Shoals Lookout and Weedpatch Hill vista are abundant. Cliffs, rock-shelters, falls, natural bridges, caves and caverns are numerous. Marengo and Wyandotte caves in Crawford County are well known in our state but they need to be more widely known throughout the Mississippi valley.

3. *Numerous and extensive wooded areas.* It is a well known fact that wooded areas are more numerous and extensive here. In this area are the greatest number and largest state parks and forests. Here we also find the greatest acreage of farmland unsuited for agriculture—farmland which after a careful survey has been recommended for forest land, recreational and residential purposes. This survey revealed that over 7 percent of Indiana has farmland unsuited for agriculture and recommended that it be used primarily for forests and recreation (1). Nearly all of this type of land is in unglaciated Indiana. For example, a preliminary survey of Monroe County (the northernmost county in which most of the county is in the unglaciated area) shows that 91,863 acres or 34 per cent of this county is unsuited for farming and is recommended for timber use. In adjacent Lawrence County, 39,800

acres have been recommended for forestry purposes. If recommendations materialize, here would be over one hundred and thirty thousand acres of forests contributing to the recreational potential in only two counties.

4. *Four distinct yet mild seasons.* From the recreational standpoint, unglaciated Indiana has four distinct yet mild seasons. There are a few hot days and a few uncomfortable ones due to exceptionally high relative humidity. Statistics show that the average temperature for the two hottest months, July and August, is below 78 degrees F. The winters are mild and short. According to some psychologists and physiologists, the human mind and body function best in a temperature of about 57 degrees F. The standard mean temperature of most of this area in October is 56 to 60 degrees.

5. *Variety of water features.* The variety and novelty of the water features add materially to the region's actual and potential recreational value. There are artesian, mineral, and "medicinal" springs. Although the surface streams and rivers are small, generally somewhere along their course are scenic shoals, rapids, falls, and cataracts. Indiana does not boast of high waterfalls, but there are many picturesque small ones. Associated with the karst topography of this area are many small underground streams which have always fascinated people. Perhaps the best known of these is Lost River near Orleans in Orange County.

6. *Wildlife and game.* Wildlife and game are valuable recreational assets. In general, whether young or old, urban or rural, people enjoy seeing wild animals in native habitats. And when some forms of wildlife are plentiful enough to be used as game, hunters and fishermen will flock to an area. Wildlife is now more abundant here than it is in other parts of the state. Quail, squirrel, rabbit, "possum", "coon", and fox hunting are popular.

7. *Historical places.* Since southern Indiana was settled first, it is only natural that much of the state's early history took place near the Ohio River. If Hoosiers want to study early "on-the-spot" history in its remaining geographic setting, they should come to southern Indiana. Here archaeologists are busy unraveling the past and writing the history of "pre-white" culture.

Conditions Retarding Growth

Some factors retarding the more rapid growth of the travel-recreation industry are:

1. *Dearth of recreational lakes.* Since most of this area is in slope, we have few natural lakes and those we do have are small. During the past year, organizations in Monroe County have been advocating a flood-control lake project in the southern part of the county. The Bloomington Daily Herald, July 12, 1949, carried a story entitled "Need for Lake, Economic, Industrial, Recreational". The story reported that a panel-discussion presented to members of the Junior Chamber of Commerce by E. B. Duane, R. W. Sims, George J. Wise, and Thomas F. Barton discussed this need. During the spring and summer of the

same year this panel appeared before various organizations in Monroe County.

2. *Deterioration of streams and rivers.* Originally our streams were spring-fed, permanent water courses, free of silt and impurities. Today, many streams have become "ribbons of desolation". Fortunately as we restore stream conditions for wildlife by reforesting the watersheds, building lakes, and discontinuing using the streams as sewers, we also increase the recreational potential of the area.

3. *Inaccessibility.* Some of the finest recreational features and areas are relatively inaccessible due perhaps to oversight in considering adequately recreational potentials in road planning. Because of the lack of information, poor roads and inadequate road markers, too many people stay on the primary roads and miss these recreational places. There is a definite need for tourist booklets, guides and maps for cities, counties, and/or the entire hill country.

4. *Lack of comprehensive study.* Although a large amount of research has been conducted and published on some phases of this area, a comprehensive regional study of the counties occupied by the unglaciated hills needs to be made (2). Many facets of the regions' setting and life remain unstudied: Published studies are scattered in dozens of different magazines and books. People living in or outside this region do not have any one adequate source to which they can turn for general information and for geographic and historical perspective. A study of this region could have as some of its objectives the following: a. present the geographic setting, b. give a geographic historical perspective of its development to date, c. picture conditions as they are today, d. assess the natural resources, e. promote the region's travel-recreational industry, f. assist its industrial development, g. crystallize the potentialities of the region, and h. in general to make available information at one source where it will be accessible to people thus enabling them to work individually, or through community, county, or a regional organization to build for a better future. The travel-recreation industry is definitely related to and its development should be correlated with other industries such as agriculture, forestry, manufacturing, and transportation (3).

Conclusion

The hills of southern Indiana are endowed with the two most potent forces that attract travelers who seek relaxation and recreation—these are a favorable physical environment and a rich historical past. Because of the nature of the land, much of the area should serve the dual purpose of providing forests and recreation. A comprehensive regional study needs to be made if this area is to be developed and used wisely.

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Distribution Patterns of Sand and Gravel Pits in Northwestern Indiana

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Introduction

Observations made during reconnaisance work on sand and gravel deposits in eighteen counties in northwestern Indiana in the summer of 1949,[1] indicate that distribution patterns do not follow closely the mapped moraines. The present study sets forth principles and attempts limited interpretation of the pit pattern.

The position of the pits on the map represent sand and gravel deposits that are under relatively thin overburden. Other deposits undoubtedly are present within and below the ground moraines, the recessional and end moraines, and the outwash aprons. Much of the gravel in the thinly covered upland has been found and exploited. These gravel deposits are now mostly worked out and are small compared with the deposits scattered along the outwash trains.

Deposits of sand and gravel associated with glacial sluiceways and recessional and ground moraines have been discovered mainly by chance. Digging of post holes for fences and power lines, digging and drilling of water wells, and construction of drainage ditches and highway grades are the common means of discovery. Thus the pit pattern herein presented shows the locations of the most easily found deposits.

General Observations on Patterns

Large vacant areas on the map do not necessarily mean that gravel is absent. Inadequate prospecting, thick overburden, distance from population, or a veneer of sand covering the outwash may have contributed to a scarcity of pits. Such areas are in Newton, Jasper, and Pulaski Counties.

Pits, though associated with end moraines in northwest Indiana, generally are not congregated at the outer edges of the moraines, but tend to be scattered across and behind the moraines. In the Valparaiso, Maxinkuckee, and Packerton moraines, pits are opened on the outwash side, within, and on the ground moraine side. This condition is especially well exemplified in the vicinity of Plymouth in Marshall County.

The pits are in widely spaced concentrations along the larger moraines. Most of these pit groups are in areas that have many kames and eskers. Many more such districts may be present, but they are scattered due to burial by over-riding ice or readvance of later ice. A typical example is five miles northeast of Logansport in Cass County.

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[1] Field project of the Division of Geology, Indiana Department of Conservation.

The lithology of the underlying rock plays an important part in the spacing of the pits. Where end moraines are built from ice moving over limestone and dolomite, plentiful gravel aggregates, and thus more pits, are present in the outwash. In the eastern part of the area, especially in Howard and Miami Counties, the gravels are mainly Silurian limestone, dolomite, and chert. Comparison of aggregates with rock in place by means of fossils and lithology are definite aids in estimating transport of bedrock to gravel pits. The distinctive lithology of the thin bedded Kokomo Limestone makes recognition possible in the deposits along Wildcat Creek. Transport of the greater percentage of the aggregates varies from zero to twenty miles. Shales in the path of ice movement furnished an abundance of clay, but only small quantities of gravel. Pits associated with the Valparaiso moraine in Porter County are in an area of clay drift and are characterized by shaly aggregates. The fragments in the aggregate are from the Devonian shales in the Lake Michigan Basin.

Interlobate areas formed large sluiceways that carried gravel far out beyond terminal moraines. The coarse gravel was carried at least

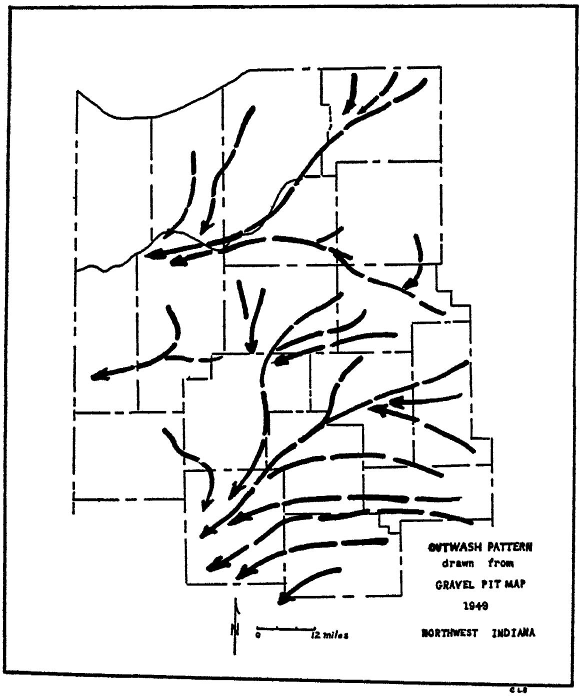

Fig. 1. Map of outwash pattern for northwest Indiana.

twenty miles. The fine gravel and sand may have been carried much farther. The Kankakee sluiceway had a number of strong tributaries entering the main torrent, which main torrent, as indicated by terraces and pits, extended southwestward from South Bend in the present Kankakee Valley. The pattern of the pits indicates that at least one main tributary originated in the vicinity of Culver from Maxinkuckee ice, and entered the Kankakee sluiceway via southern Starke County. The Wabash Valley was another major sluiceway. However, part of the gravel came from reworked outwash of the Packerton ice, and from minor sluices flowing westward across Howard, Carroll, and Clinton Counties.

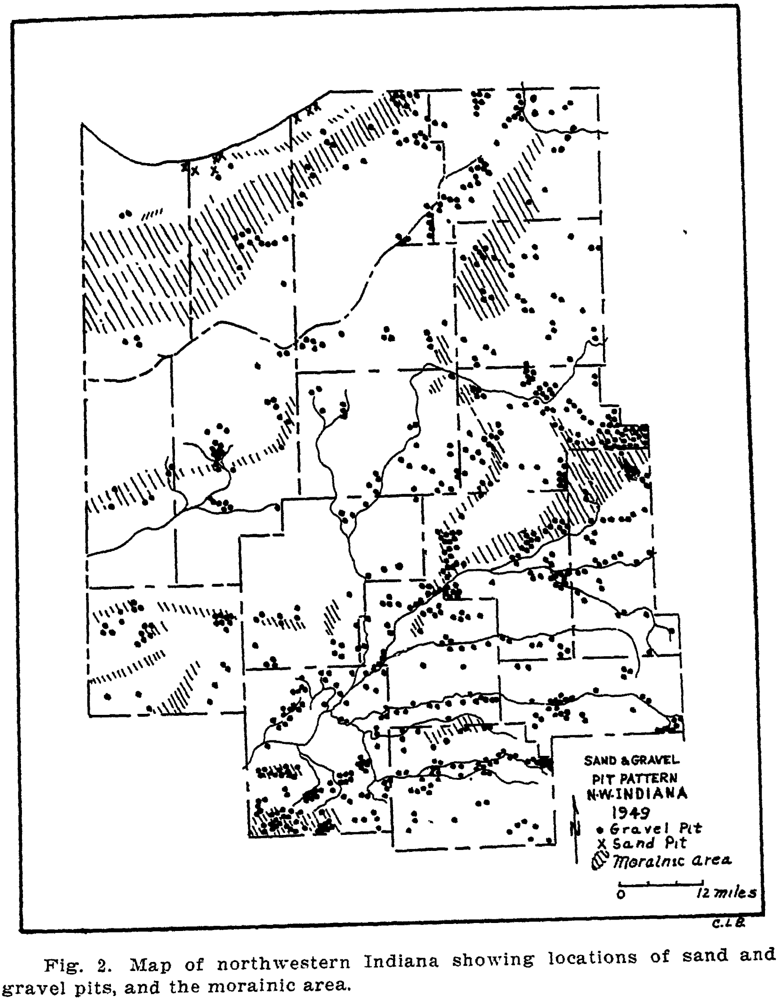

Fig. 2. Map of northwestern Indiana showing locations of sand and gravel pits, and the morainic area.

Undesirable materials in the aggregate such as shale fragments, weathered chert, and ocherous clay are deposited along sluiceways for distances as much as fifty or more miles. The great volume of water and the low specific gravity of the chert, clay, and shale fragments account for their dissemination. In the southeastern part of the area, Wildcat Creek flows across till and drift that contains cherty limestone. Most of the pits scattered along Wildcat Creek in Clinton and Tippecanoe Counties contain a small percentage of weathered chert. These cherts were carried down the Wabash sluice for fifty or more miles.

The pattern formed by all pits, active, inactive, and abandoned, shows several definite outwash areas. (Fig. 1). The lines of outwash generally simulate the present drainage pattern, but exceptions are found when locations of old glacial channels are interpreted from the positions of the pits on the map. One outstanding example is a line of pits across southern Starke County in the Kankakee Basin.

Conclusions

Gravel pits in northwest Indiana follow the present drainage pattern rather than the morainic pattern. Though more pits have been operated in morainic districts, the largest pits are located in front of the moraines along the outwash trains. Maps, such as Fig. 2, showing the location of all pits, active, inactive, and abandoned, are tools for studying patterns of outwash.

The Grand Portage Fur Traders Route and Indian Reservation

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Extending southwest and west from the point where the International Boundary touches Lake Superior at the mouth of the Pigeon River between Minnesota and Ontario is a sparsely populated and isolated region of relatively little economic importance. This condition stands in sharp contrast to the situation that prevailed here in the eighteenth century and reflects dynamic relations to the physical and cultural setting both within the region as well as outside of it, operating within a framework of national and international interests.

This region, extending along what is now the International Boundary, was of major significance as long as the fur trade flourished in this part of North America, since it offered a canoe route that extends more directly and farther westward than does any similar route from the edge of Lake Superior.

Penetration of the continent by the explorer and fur trader who came by way of the St. Lawrence and the Great Lakes had been fairly easy as far as the western edge of Lake Superior. At this point, however, the Laurentian Upland stretches southward and westward between the Lake Superior basin and the prairies and constitutes a barrier to transportation.

The eastern edge of this region, where streams descend from the upland level to that of Lake Superior, has been made particularly rugged by the interaction of erosive forces on irregularly distributed rocks of varying resistance. Long, even-crested ridges, rather irregularly distributed, rise steeply to a height of as much as 600 feet above valley bottoms. Few stream valleys extend more than a few miles inland, most of them contain only shallow, bowlder filled streams and nearly all of them consist of narrow gorges while the river courses themselves are marked by falls and rapids.

Farther inland the relief is less, but irregularly distributed lake filled depressions made the development of satisfactory transportation routes no less difficult.

However, from a point near the center of the northwestern shore of Lake Superior a series of short, but deeper and wider rivers connecting a chain of lakes, stretches almost directly westward to the Lake of the Woods on the western edge of the upland. This route not only provided access to this region, but was the shortest route through it for canoe transportation and in addition provided access to the headwater region of the Mississippi and to drainage basins leading to Hudson Bay and to the Arctic.

Although this route was direct, falls and rapids nevertheless made many portages necessary, thirty-six to be exact. The longest of these was the Grand Portage that extended from a point several miles south of the mouth of Pigeon River westward about nine miles to the river to avoid a series of falls and rapids in the lower course of the stream.

Used intermittently by French fur traders after 1731 it became the usual route for English fur traders after 1760. However, it was the Northwest Fur Company, organized in the late 1770's that made the route famous.

This company established a trading post at the Lake Superior end of the Grand Portage to which the name Grand Portage was given. A supply depot and fort, called Fort Charlotte, was established at the Pigeon River end of the portage. A number of other way stations, depots, and forts were set up along the entire route. A fort and trading post of major importance was Fort Frances at the outlet of Rainy Lake, since it was here that furs from the south, west, and north were assembled before being shipped to Grand Portage.

Grand Portage became the great fur trading post of the Northwest Company, at which furs were assembled from the entire tributary area in the early summer. The fur trade in this region also attracted traders from the American Fur Company and the Hudson's Bay Company and competition became keen and sometimes bitter. However, the strongly entrenched Northwest Company was easily able to maintain its position in the region.

With the Louisiana Purchase in 1803 a new problem faced the Northwest Company. The government of the United States began negotiations with Great Britain for the establishment of a boundary. Although the boundary was not fixed until 1842, the United States so strongly claimed this region that the Northwest Company, fearing intervention by American Customs officers, transferred its main base of operations to Ft. William in 1803 and Grand Portage ceased to be a great focal point in the region. The American Fur Company later established a trading post here but Grand Portage never again regained its former importance.

Fixing of the International Boundary at the line of the Pigeon River and the Border Lakes in 1842 divided the region, and the process of slowly drawing each of the parts into a framework of separate national interests was begun.

That part of the region that lies south of the boundary held few attractions for private development after the fur trade had declined, and in 1854 the eastern part of this region was established as a reservation for the Chippewa Indians, occupying, as it does, a part of original tribal hunting grounds.

The discovery of iron in the Vermillion and Mesabi ranges and the techniques for using those ores was followed by rapid and intensive development to the south of the older fur route. Rail lines were built to connect the iron mines with Lake Superior ports at Two Harbors and Duluth. With connections to the south and east already established, Duluth became the new gateway to the west and northwest; agriculture, industry, and mining offered greater returns at the margins of the region than within it, and this once great focus of transportation became an isolated outlying region. Effectively cut off from the principal routes of land travel in the United States by the southwestward trend of Lake Superior and with no good connections with those routes this region became a remote cul-de-sac.

When lumbering began in the upper Great Lakes region, about 1895, this region had a period of short-lived importance as a source of good quality white pine. White pine forests were the natural vegetation while the lakes and rivers provided a means of transportation to Lake Superior ports for shipment out of the region. The forests were removed also from the reservation by lumber companies that either purchased the land or acquired timber rights.

The focus within the region during the lumbering period was the mouth of the Pigeon River. Not only was the assembly of logs at this point simplified by the large number of lakes to which tributary streams are joined, but the mouth of the stream is sufficiently deep to serve as a harbor which opens into a large protected bay. A small lowland at the mouth of the river provided a good site for lumber camp, sawmill, and storage yard at the harbor's edge.

Nevertheless, the region during the lumbering period never achieved so prominent a position as a focus for transportation lines as had been true in the earlier period. Lumbering operations were carried on at the mouths of other streams entering the Great Lakes so that this was only one of many similar developments.

A large part of the original reservation passed into private ownership during and immediately after the lumbering period through sale and homestead privilege. There has been an attempt to consolidate the reservation in recent years, reflecting a change in government policy and resulting in the purchase of privately owned land within the limits of the reservation as it becomes available. This has been aided by the abandonment of many homesteads within the region. Of the 60,000 acres of land within the reservation only about 6,000 are still privately owned, although mineral rights have in some cases been retained by earlier owners.

It has been estimated that about 300 Indians live on the reservation. Most of these live along the road that extends from Mineral Center to Grand Portage, along roads that branch out from Grand Portage, or at Grand Portage itself.

Grand Portage is the center for the reservation. It consists of a trading post, a post office, church, school, community house, several cabins for tourists, and a stockade and lodge built in 1941 on the site of the original trading post, the lodge now serving as a restaurant.

A few of the Indians have found full-time employment in forestry and commercial fishing, others have part-time employment as caretakers of the few summer homes on the reservation, in carpentry, or the manufacture of handicraft articles, while nearly all supplement a meager income by trapping and hunting.

Very little agriculture is carried on. Most of the area included within the reservation consists of birch and poplar covered hills and valleys. Occasional clearings in the forest are in many cases the remains of agricultural settlements established by German and Irish immigrants in the early part of the present century. However, agriculture was never very successful here, and by 1938 nearly all of the farmers had gone elsewhere.

The Indians raise potatoes and cabbage and a few other vegetables. There are no cattle on the reservation and only one family was found that had any poultry.

The soil derived from the slate which underlies nearly this entire region is poor and in most places thin. The growing season is short. A large part of the region has slopes which are too steep or too rocky for cultivation. Nevertheless the lack of interest in agriculture reflects not only the restrictions imposed on farming in the local area, but reflects a way of living that appears more desirable to the Indian than the routine involved in agricultural production.

Forestry does not support the Indians here. Although nearly all of the reservation land is forested, a large part consists of birch and poplar too small even for pulp wood. Furthermore, the Federal Government has designated this as a Wilderness Area, thereby prohibiting commercial lumbering without special permission.

Hunting and fishing provide part of the food supply. Trapping contributes somewhat to the income but beaver, the most valuable of the fur bearing animals in this region, were almost depleted. The colony is growing at present and with trapping regulated by the tribe in such a way that only a certain proportion of the estimated beaver population may be taken in any one year, there is hope that this activity will make a greater contribution to Indian support in the future.

The tourist trade provides only a relatively small source of income. Fishing and boating on Lake Superior are at present almost the only attractions to tourists outside of the beautiful setting. Furthermore, since Grand Portage lies several miles off the highway and is connected with it only by a gravel road, only a small fraction of the passing tourists have been sufficiently interested to turn off the highway and investigate its attractions.

There is hope among some of the Indians that a contemplated relocation of Highway 61 to bring it through Grand Portage will increase the tourist traffic. If such a relocation takes place, intelligent catering to tourist needs may indeed be of benefit to the Indians, but up to the present little initiative in this direction has been shown.

There is much of scenic beauty and historic interest within the limits of the reservation. The Grand Portage, the site of Ft. Charlotte, and the site of the trading post at Grand Portage are all of historic significance, yet following the Grand Portage route to Ft. Charlotte and returning on foot through the forest probably has little appeal to the average tourist.

The hills, overlooking the village of Grand Portage offer a splendid view of the surrounding region and can be climbed with little difficulty. Middle Falls and High Falls in the Pigeon River at the edge of the reservation are likewise of scenic interest. At present neither is accessible from the American side although both have not only been made accessible from the Canadian side but provided with facilities for tourists as well.

Handicraft articles are of interest to tourists, yet few such items are available within the reservation, none that reflect particular tribal skills or culture.

The Indians on this reservation have not become self-supporting. This is indicated by the fact that 85 per cent of the county relief funds are reported to be used for their support. This condition does not permit a fair appraisal of the ability or resourcefulness of the Chippewa Indians since reservation development is related in part to government policy and in part to the fact that a large part of the capable and ambitious younger men and women have been attracted by better opportunities elsewhere. This is reflected in the fact that a large part of the resident population is either above 60 or below 18 years of age.

Mineral Center is the site of an abandoned non-Indian agricultural settlement. At present only one Indian family lives there.

Hovland, just outside the reservation has almost no commercial contact with the Indians. Grand Marais serves as the commercial and governmental center of the region. Here are the county offices, courts, and high school as well as the center for the border patrol.

Within the limits of the reservation is one other center, namely at Pigeon River which functions as a port of entry and a small tourist center. These two activities form the basis for the entire local settlement.

The highway crossing into Canada at this point extends from Duluth to Fort William and is the only land route joining these adjacent regions between Lake Superior and International Falls. This highway is the only means of access to this region by land from either the American or Canadian side and provides the only connection that this region has with American or Canadian transportation lines.

Customs and immigration officers on opposite sides of the river here reflect separate national interests along a stream that at one time served to unite the entire region. The highway likewise emphasizes a difference in the region, not only with respect to the change from water to land transportation, but also with respect to the change in the direction of movement since the trend of the highway is dominantly north and south in contrast to the earlier east and west movement.

These contrasts reflect the changing relations of a dynamic culture to the physical setting; relations that have brought about a decline in the relative importance of the region and may continue to do so or that may at any moment again reverse the trend.

The Trade Area of Terre Haute, Indiana

JAMES LEE GUERNSEY, Indiana State Teachers College

Introduction

Within the last few decades, increasing use of machinery in industries, together with improved methods of transportation, have located most business functions at the points most favorable to raw materials, power, labor and markets. At the points most favorable, where the greatest number and most valuable resources can be assembled at the lowest cost, our largest cities have developed. At less favored locations the urban centers have been smaller. These urban areas largely supply the demand for necessary consumption goods, for to produce such goods elsewhere would be less profiitable.

With this growth and expansion of urban areas many problems have arisen, and in order to eliminate wasteful procedures, the need for careful, scientific studies is arising to an increasing degree. One specific problem (of which present published materials are discouragingly meager) is the establishment of an urban center's trade area.[1]

The major objective of this study is to limit the extent and to establish the boundary of the trade area of Terre Haute. Theoretically, the city's trade area is circular in outline, but in detail it revealed several irregularities. These irregularities are a result of a variety of factors, among which are the location of other urban centers, the location and condition of roads, personal preferences, the character of the products marketed, and the means of transportation possessed by individual families.

Location, Size, and Position

Terre Haute, located at 39°28′ North Latitude and 87°25′ West Longitude is the county seat of Vigo County, and at the 1940 census was the sixth largest city in Indiana with 62,693 people or 1.97% of Indiana's population.

When the factors which have contributed to the city's growth and development are examined, no difficulty is found in explaining its size. Specific factors which have contributed to its growth are (1) the central location with respect to other urban centers. (2) The location in the heart of Indiana's bituminous coal industries. (3) The favorable transportation facilities with United States highways 40 and 41 converging in the city, along with State Highways 42, 46, and 63. Also four railroad systems form a total of eleven railroad lines radiating from the city. These specific factors, along with numerous general favorable factors have contributed to the city's growth and extensive trade area.

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[1] Trade area is that geographical area in which an urban trading center exercises the dominant commercial influence.

Newspaper Trade Area

The role of the newspaper seems to be one of the best "measuring sticks" for determining the extent of the city's trade area. Modern means of transportation and communication have greatly widened the trade area and the newspaper has superseded the town crier as a publicity agent. For throughout the circulation area of the city's newspapers, most prospective customers for Terre Haute merchants can be reached. Local as well as international news is reported in the newspapers; therefore satisfying the needs of the surrounding area and creating a medium for advertisements by the local merchants which reaches the majority of their prospective customers.

The Terre Haute Star and The Terre Haute Tribune are the city's only daily newspapers. The Star is a morning paper while the Tribune appears every week-day evening. Their total average net paid circula-

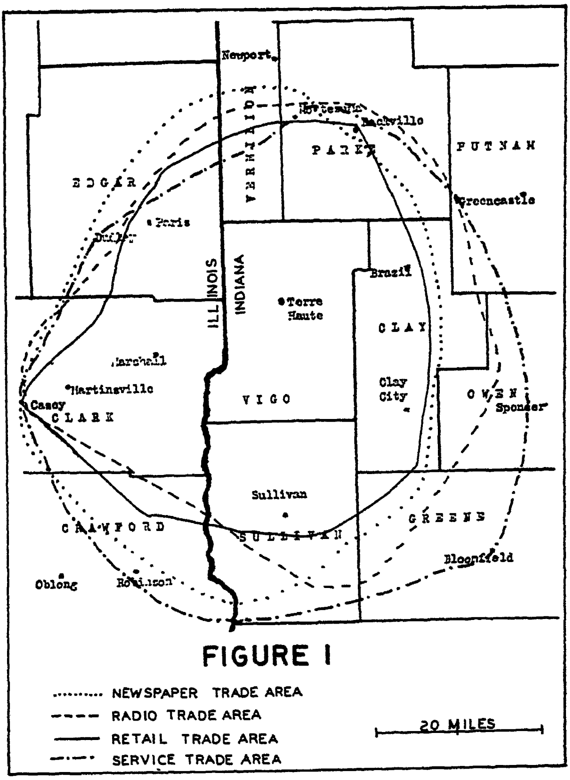

Fig. 1. The trade area of Terre Haute, Indiana.

tion in 1948 was 26,900 for the Star and 28,594 for the Tribune giving a total of 55,494 for the combined morning and evening newspapers. On Sunday the two papers combine their efforts and publish The Terre Haute Tribune-Star which average 38,251 copies each week. Of the 55,494 copies of the daily newspapers sold, 20,020 copies were sold to people living outside the city limits.

In figure 1 is shown the geographical area in which either The Terre Haute Star or The Terre Haute Tribune leads in circulation over other newspapers. This is one indicator as to the extent of Terre Haute's trade area.

Retail Trade Area

Terre Haute can be conveniently reached by United States highways 40, 41, and 150 and Indiana highways 42, 46, and 63. These hard surface roads, which radiate out in all directions, have enabled the city to build up a large retail trade.

United States Highway 40 (the National Road) is the most used thoroughfare through the city. The main retail center of the city is along Wabash Avenue as it is the street on which the National Road extends through the city. This retail zone extends from the Wabash River east to about 17th Street along Wabash Avenue. There has been a slight tendency to build retail stores a block or two away from this east-west traffic artery, but most of the larger retail stores have their frontage on Wabash Avenue. Smaller retail stores farther from the central business district usually serve only limited trade areas.

TABLE I. Retail Statistics

Town	Population	People per Store	Number of Stores	Total Sales (000)	Sales per Store	per Sales Person
Evansville	97,062	63.8	1521	$45,234	$29,740	$466
Hammond	70,184	81.	867	31,858	36,740	453
Muncie	49,720	64.	778	23,511	30,220	470
South Bend	101,268	67.4	1502	47,996	31,955	474
Terre Haute	62,693	53.7	1167	33,668	28,850	539

The retail statistics as gathered from the 16th census of the United States, which are indicated in Table I, were calculated in terms of dollars per inhabitant per year for Terre Haute and the four other Indiana cities of similar population and size. The sales per person is higher for Terre Haute than for any of the four other cities. This is indicative of the wide area which is dependent upon Terre Haute as a trade center for the per capita effective buying income of Terre Haute citizens is not unusually high.

The total retail sales for the 1,167 retail stores of the city amounted to $33,668,000 in 1939.[2] In comparison with all other cities of Indiana in

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[2] Sales Management figures reveal that the total retail sales during 1947 amounted to $83,379,000 as contrasted to $33,668,000 in 1939. *Sales Management*, The Magazine of Marketing. May 10, 1948.

1939, Terre Haute ranked fourth in total retail sales. The population of Terre Haute made up 1.97 per cent of the State's total population, yet 3.2 per cent of the state's total retail sales took place within the city. This fact is indicative of the dependence that the surrounding population have upon Terre Haute as a retail trade center.

The fewer people per store (as found by dividing the city's population by the number of retail stores in the city) further substantiates the assumption that Terre Haute has a "greater than average" trade area. The above average number of stores per 1,000 people again points out the dependence of the retailers upon customers who reside outside the city limits.

However, the sales per store are less than the other four cities revealing the greater number of retail stores per 1,000 people. The average sales per store in Indiana cities of similar size was $31,000 as compared to only $28,850 in Terre Haute. This is partly the result of the large number of groceries, meat markets, fruit stands, eating and drinking places, and filling stations whose sales are below the State average.

Table II lists the nine counties to which the $83,379,000 of retail products were sold in 1947. Figure 1 indicates the estimated retail area of the city based upon those 1947 total retail sales figures.

Table II

Indiana County	1947 Total Retail Sales (000 omitted)
Vigo (Terre Haute)	$39,981
Clay	6,335
Greene	6,653
Parke	3,753
Sullivan	5,257
Vermillion	5,256
Illinois County	
Crawford	5,916
Clark	3,076
Edgar	7,152
Total Market	$83,379
Terre Haute	36,600
Balance of Trade Area	$46,779

Radio Trade Area

The area reached by the two Terre Haute radio stations is another means by which the extent of the city's trade area can be scientifically estimated. Unfortunately the daily broadcast reception is not the same since it varies with atmospheric conditions. The station's coverage also varies in reception range from day to night. Therefore, the number of listening families within an area varies with the reception received.

In 1946, The Broadcast Measurement Bureau made a study of the extent of the daytime and nightime listening audiences of Radio Station WBOW. Table III indicates the result of this survey with the blank spaces denoting listening audiences of less than ten per cent of the total radio families in the county. Table IV, according to 1946 Sales Management Figures, indicates the breakdown of the total population and radio families which make up WTHI's listening audience.

TABLE III

State	County	Radio Families	Daytime Families	Audience Per Cent	Nighttime Families	Audience Per Cent
Illinois	Clark	4,340	1,000	23	720	16
Illinois	Edgar	6,550	1,440	22	920	14
Indiana	Clay	5,630	3,380	60	2,130	37
Indiana	Greene	7,000	1,580	22		
Indiana	Owen	2,470	330	13		
Indiana	Parke	3,840	930	24		
Indiana	Sullivan	5,490	2,020	36		
Indiana	Vigo	26,450	20,240	76	20,540	77
Indiana	Vermillion	4,870	1,930	39	1,370	28
WBOW's Total			33,850		25,680	

TABLE IV

County	State	Total Population	Total Radio Families
Vigo	Indiana	97,400	26,450
Sullivan	Indiana	22,500	5,490
Clay	Indiana	22,600	5,630
Parke	Indiana	15,300	3,840
Greene	Indiana	27,700	7,000
Clark	Illinois	16,200	4,340
Edgar	Illinois	23,100	6,550

Total Population within coverage of WTHI 224,800
Total Radio Families 59,000

From Tables III and IV an approximate radio trade area can be determined. This generalized radio trade area is shown by figure 1.

Service Trade Area

Since the attraction to the consumer market is the ruling force in the location of the service industries it seems that service trade areas may be used as a bases for establishing a city's trade area. So another source used for attempting to establish the extent of Terre Haute's trade area is the service companies and service departments of some of the larger retail stores.

Questionnaires were sent out to service companies and some were personally visited by the writer. Several service companies had a trade area that included only Vigo County and due to the politically determined trade area their data remained unused. Detailed information was available at the service departments of some of the larger retail stores as they maintain daily service routes. These routes usually extend about thirty-five miles from Terre Haute, with the distance depending primarily upon the location of other company stores. The questionnaire returns revealed the total average radius of the service trade areas to be 37.5 miles. Figure 1 indicates the city's service trade area as determined from this data.

Conclusions

This is an attempt to determine the extent of the trade area of Terre Haute, the area in which farmers ordinarily market their products, and upon which they in turn depend for goods and services which they need. The boundaries of the newspaper, retail, radio, and service trade areas are shown as overlapping. It is recognized that their limits can not be drawn with mathematical precision, although it is believed that they represent to some degree the actual functioning parts of Terre Haute's internal commerce.

Internal free trade has permitted the structure of the city's trade area to develop without any relationship to political areas. Still, sales plans and records, in most cases, are broken down by major political divisions, although they fully realize the trade area is of more importance to them. Yet the policy of collecting population and other statistics is carried on by conforming with political boundaries due to custom and convenience.

The trade areas seem to bear but little direct relation to physiographic features. The rivers and the moraine areas have had no traces of "adjustment" to the trade areas. What seems to have affected the areal pattern of the Terre Haute trade area is not so much the political divisions or the topography but mainly the location of other urban areas, the distribution and density of population, the layout of transportation routes, and trade traditions inherited from the past.

Ground-water Levels in Indiana[1]

FRED H. KLAER, JR.,[2] U. S. Geological Survey

Introduction

Water has always been recognized as one of the necessities of life, and water from underground sources obtained through wells and springs has played a major part in the development of our modern world. The existence of the early nomads mentioned in the Bible was controlled largely by the sources of water supply and by the locations of existing wells and springs. In our modern world, however, because of the seeming ease with which the average citizen is supplied with water, with little or no effort on his part, the difficulties in obtaining adequate water supplies are often overlooked.

In 1935 the Indiana Department of Conservation, realizing the importance of ground-water supplies in the agricultural and industrial development of the State, began an observation-well program in cooperation with the United States Geological Survey. A number of wells were selected for observation and measurements of water level in the wells were made at regular intervals. This program has continued to date. Also, a small-scale study was made of the ground-water conditions in the heavily pumped Indianapolis area (5). In 1943 the Indiana State Legislature appropriated funds for expanding the cooperative water-resources investigations of the Department of Conservation and the U. S. Geological Survey. The observation-well program was enlarged and now includes 170 wells throughout the State.

Importance of Water Levels

The rocks and other surficial materials of the earth's crust nearly everywhere contain openings of one sort or another, in which water is stored. The type and size of these openings vary within wide limits, and therefore the rocks containing them vary widely in their capacities to store and to yield ground water. The zone in the earth's crust in which the openings in the rocks are filled with water is called the *zone of saturation.* The top of this zone, except where the top is formed by an impermeable formation, is the water table and its position is shown in a general way by the water levels in wells. In formations where the top of the *zone of saturation* is formed by an impermeable cover, the water levels in wells generally will rise above the bottom of the impermeable cover and the water in the formation is said to be under

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[1] Published by permission of the Director of the U. S. Geological Survey.

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artesian pressure. Under artesian conditions, the surface represented by the water levels in wells is the pressure-indicating or *piezometric* surface.

The rock formations of the earth's crust are large underground reservoirs which are replenished by water from precipitation and, where the water table is below the level of lakes and streams, by seepage from those bodies. Water is removed from the reservoir by natural drainage through springs and into streams, by evaporation and transpiration or plant use, and by withdrawal from pumped or flowing wells. The stage to which the reservoir is full, under water-table conditions, is indicated by the water levels in wells.

The ways in which rainfall is dissipated is shown by the hydrologic cycle or water cycle. Water falls on the earth as rain, snow, or hail. Part of it evaporates as it falls, part is intercepted by plants and trees before it reaches the earth, and the remainder reaches the land surface. In turn, part runs off as surface flow into streams and lakes, part is evaporated from the land surface, and another part seeps into the ground. Of the portion that seeps into the ground, part is used by plants and is returned to the atmosphere, and part eventually reaches the zone of saturation, from which it drains naturally into surface streams and lakes or is recovered by wells. It is estimated that, of the total precipitation in Indiana, an average of 65 to 72 percent is lost through evaporation and transpiration, 8 to 20 percent runs off directly as surface runoff, and 10 to 20 percent is recharged to the ground-water reservoir, from which it is later discharged naturally or through wells.

Observation-well Program

The observation-well program which was started in 1935 included 46 wells, mainly in the northern half of the State. These wells were measured by personnel of the Indiana Department of Conservation, the Civilian Conservation Corps, the Soil Conservation Service, and various municipalities. The program has been expanded to include 170 wells at present, the majority of which are measured at weekly intervals and 35 of which are equipped with automatic recorders that give a continuous record of water-level changes. The locations of these wells are shown in figure 1.

The wells selected for observation purposes are unused wells that have been abandoned for one reason or another. They include wells of all types. They have been selected mainly on the basis of geographic distribution, considering, however, local geologic and topographic conditions. The main purpose of the observation-well program has been to determine the seasonal variations and general long-time trends in ground-water levels and to study the relation between rainfall and ground-water levels in different parts of the State.

Water-level Fluctuations

The water level in a well is nearly always changing in response to the effects of natural and artificial influences. It is affected by rainfall,

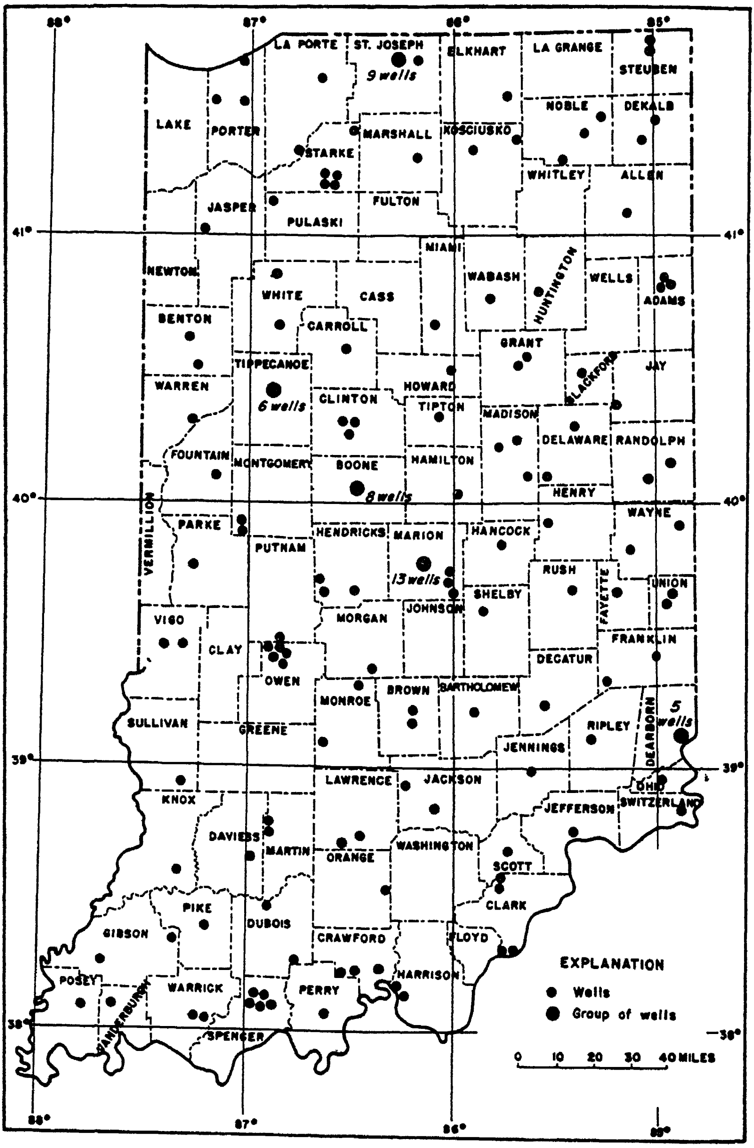

FIGURE I. OBSERVATION WELLS IN INDIANA - 1948.

and individual storms of several inches of precipitation may cause water levels to rise several feet in some wells. The relation between precipitation and ground-water levels in Indiana is much closer than is generally realized, and trends in ground-water levels follow closely the trends in precipitation.

Water levels in wells are also affected by recharge from nearby lakes and streams; by losses due to evaporation and transpiration, pumping from wells, and natural drainage into surface streams; and by minor factors such as changes in barometric pressure, passage of railroad trains, earthquakes, ocean tides, and earth tides. The potential effects of these various factors must be considered in the comparison of water levels measured at different times and in different wells.

In order to determine trends in precipitation for comparison with trends in water levels, a graph of the cumulative departure from normal precipitation was plotted, using the average annual precipitation data for the State as determined by the U. S. Weather Bureau. When precipitation is above normal the curve rises, and when precipitation is below normal the curve falls. The excesses and deficiencies in precipitation are added algebraically, giving the curve shown in figure 2.

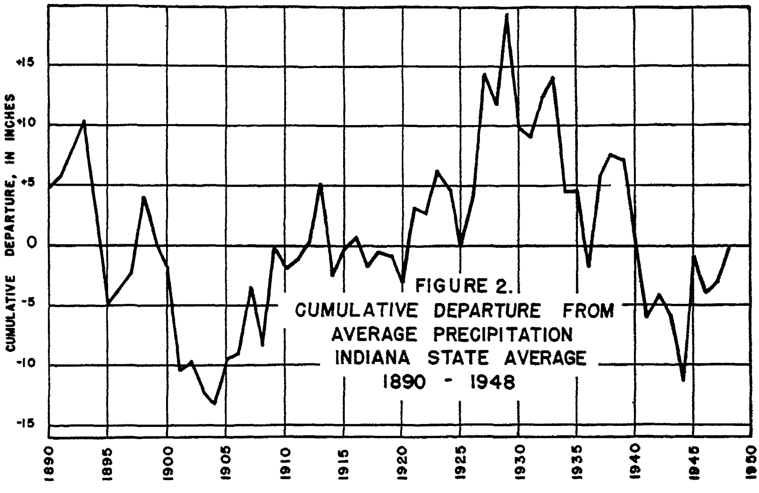

Figure 2. Cumulative departure from normal precipitation in Indiana.

In the 62 years of record, the general trend in precipitation was downward from 1893 through 1903, predominantly upward from 1904 through 1929, generally downward from 1930 through 1944, and has been somewhat upward since 1944. It is interesting to note that the cumulative deficiency in precipitation was greater in 1904 than in 1944. It should be noted also that the cumulative-departure curve from 1929 through 1944 dropped from an excess of 19.48 inches to a deficiency of 11.40 inches, a total of 30.88 inches, nearly 80 percent of a year's precipitation.

General Trends in Ground-Water Levels

Before discussing in detail the trends in ground-water levels in Indiana, several general facts must be considered. When water is pumped from a well, the water level in the well must be lowered in order to cause additional water to move into the wells to replace that which is pumped out. The water level in the formation around the well is also lowered, causing a depression in the water table that is shaped more or less like an inverted cone. This lowering is called the *cone of depression.* When many wells in a given area are pumped, the individual cones of depression often merge and a regional cone of depression is developed. The size and shape of the regional cone of depression are determined by many factors, the most important of which are the thickness, permeability, and storage capacity of the water-bearing material and the quantity of water being pumped. The cone of depression normally will continue to expand until the quantity of recharge occurring within it is equal to the quantity of water being pumped. In most areas, both the recharge and the pumpage vary from day to day, and thus the cone of depression seldom remains constant in size or shape. A decline in ground-water levels does not necessarily indicate overdevelopment of the available ground-water supplies of a given area, but may indicate merely the normal expansion of the cone of depression necessary to cause the required quantities of water to flow to the wells from which it is pumped.

The increased efficiency of pumps and the widespread use of electricity have greatly increased the use of water. Because it is easier to pump larger quantities of water now than it was 20 years ago, many new uses have been found for water and the average requirements for water have been steadily increasing. The increased use of water for industrial processes and for air conditioning and cooling, and the increasingly widespread use of water in rural areas for sanitary plumbing facilities, washing, and cooling, have placed a much greater demand on our sources of water. It has been estimated that an average of about 20 billion gallons of ground water a day was pumped in the United States during 1945, nearly twice the quantity pumped during 1935 (2).

The increased use of water is something that many people fail to appreciate. It is easy to turn on a faucet or press a button to turn on a pump, and as long as the water is there, why worry about it? Yet, many of the wells supplying these increased demands were never originally developed to yield as much water as they do now. A well that supplied 10 gallons a minute 15 years ago may have provided all the water that could be used, particularly if it was pumped by hand, and there is no reason why it should be expected to produce 25 or 50 gallons per minute at the present time after 15 years of use.

Water levels throughout the State fluctuate seasonally, and the amount of seasonal change is greater than many people realize. Ground-water levels generally reach their highest stage in the spring, usually decline through the summer months, and reach a low stage sometime between October and January. During the late winter and spring, they usually rise again. The seasonal variations in ground-water levels in

Indiana are as much as 20 or 30 feet in some wells. The comparison of a water level measured at one season of the year with that measured during a different season of an earlier year often gives misleading results.

In 1912, W. J. McGee (4), of the United States Bureau of Soils, obtained information on changes in ground-water levels on a nationwide basis by sending out questionnaires. The records of nearly 29,000 wells throughout the United States were tabulated by counties. On the basis of his study he found that "the total lowering (in ground-water levels), since settlement . . . was 14 feet or over in Indiana . . ." This statement has often been used in discussion of general trends of ground-water levels. The validity of McGee's conclusion has been questioned by O. E. Meinzer (6), late Chief of the Ground Water Division (now Ground Water Branch) of the U. S. Geological Survey, on the basis that McGee's detailed facts do not support his major conclusion, that his questionnaires were sent out and were returned largely in September, a month in which water levels are normally at a low stage, and that 1910 was an unusually dry year throughout the United States. Although in Indiana the rainfall during 1910 was only 2.58 inches below the average, the water levels were probably lower than normal because of deficient precipitation during the spring months when recharge usually occurs.

In Indiana, where the period of detailed water-level records is short. generally not exceeding 14 years, it has not been possible to estimate the average change in the State since settlement began. In 1907 a field investigation of the ground-water resources of north-central Indiana was made by F. G. Clapp and S. R. Capps (1). During the investigation water levels were measured in many wells, some of which have been measured again in recent years, particularly in the Indianapolis and South Bend areas. Although little is known about the wells measured in 1907, and point from which the well was measured, and whether nearby wells were being pumped, a comparison of water levels in 1907 with those measured in recent years will show that water levels have declined to some extent, mainly in the areas of heavy ground-water pumping.

In the Indianapolis area, McGuinness (5, p. 43), has shown that "in 11 wells in limestone, mostly outside the downtown district, the declines in water level from 1907 to 1940 ranged from less than 1 foot to about 35 feet and averaged about 15 feet. Two wells in limestone showed net rises during the same period, largely because of decreased pumpage from limestone in 1940. In one gravel well in the north-central part of the city, the water level in 1941 was 9 feet lower than that in 1907 and in another gravel well in the southern part of the city, the water level was about the same in 1940 as in 1907. According to these and other available data, the decline in water levels that has accompanied the development of the ground-water resources of the Indianapolis area has ranged in different parts of the area from a few feet to more than 50 feet. The largest declines have occurred in the downtown district where during the summer of 1941 the water levels in wells in both gravel and limestone were more than 50 feet lower than the reported original levels." Similar declines are reported in other industrial districts within the Indianapolis area.

Fragmentary information on water levels in South Bend indicates that water levels have declined an average of about half a foot per year over a period of nearly 50 years (6). It is concluded that this decline has been necessary in order to develop the ground-water resources of the South Bend area. Other industrial areas in the State where records show that water levels have apparently declined include Frankfort, Lebanon, and Marion, and similar declines have doubtless occurred in many others, for which information is not now available.

The graphs of three wells in different parts of Indiana have been plotted for the period of record to show typical examples of natural water-level fluctuations (Fig. 3). Well Steuben 1 is in the northeastern corner of the State, in an area of glacial moraines of rolling topography.

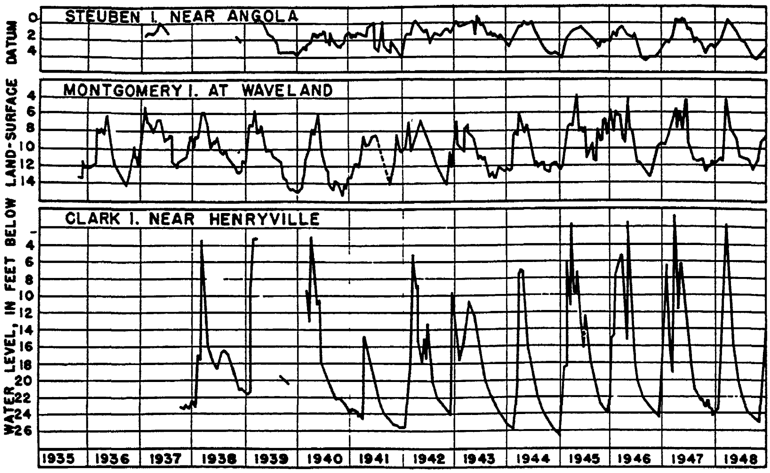

FIGURE 3. GRAPHS OF WATER LEVELS IN OBSERVATION WELLS IN INDIANA.

Figure 3. Graphs of water level in Steuben 1, Montgomery 1, and Clark 1, Indiana.

The seasonal fluctuation is about 4 feet and no serious decline in water level has occurred during the past 10 years. Well Montgomery 1 is in west-central Indiana in an area of gently rolling topography. The seasonal variation in water level is 8 to 10 feet and the general trend since 1940 appears to be upward. Well Clark 1 is in the southern part of the State in a wooded area of gently rolling topography. The seasonal fluctuation in water level is 20 to 24 feet and the general trend has been slightly upward since 1941. None of these wells are affected by pumping and the water-level fluctuations are rather typical of those in wells in rural areas where a relatively small quantity of water is pumped from the ground. The main causes for the differences in seasonal range are differences in precipitation and in storage capacity of the water-bearing materials.

Graphs of water level in areas of heavy pumping from wells show similar seasonal changes, although the changes are usually greater and occur at a slightly different time in the year, largely because of seasonal pumping. These water levels generally start to rise at or shortly after the end of the air-conditioning or cooling season and reach their highest stage in March or April.

The graphs of water levels in downtown Indianapolis show typical seasonal changes in ground-water levels in areas of heavy commercial and industrial pumpage (Fig. 4). Well Marion 2 is a gravel well near the center of the downtown area, and Marion 10 is a limestone well somewhat farther from the center of pumping. The sharply declining trend prior to 1941 was caused largely by deficient precipitation and relatively high rates of pumping. The rising trend since 1941 is doubtless due to normal precipitation and to somewhat decreased industrial pumping.

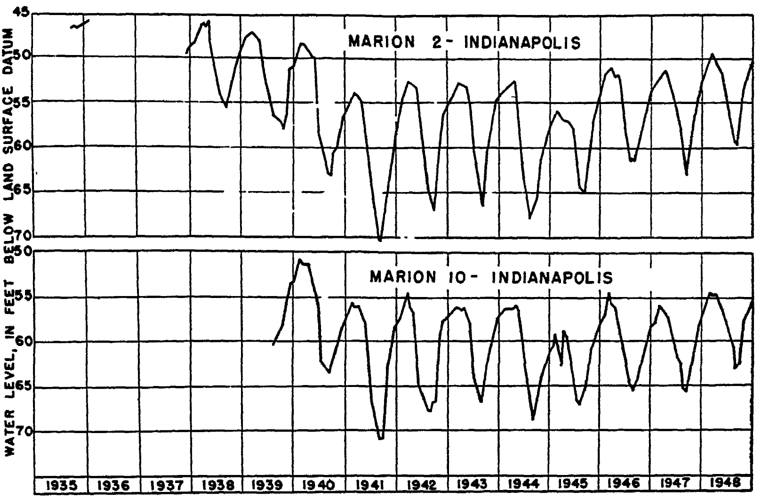

FIGURE 4. GRAPHS OF WATER LEVELS IN OBSERVATION WELLS IN INDIANAPOLIS, INDIANA.

Figure 4. Graphs of water levels in Marion 2 and Marion 10, Indianapolis, Indiana.

Conclusions

It has been shown that ground-water levels are affected by many factors, the most important of which are precipitation and pumping from wells. The seasonal change in water levels generally exceeds the change from year to year, and comparison of water levels in a well at different seasons of the year may lead to erroneous conclusions. The use of water from wells has increased tremendously, much more than is generally realized, and a large increase in pumpage must necessarily result in a lowering of water levels.

We have often been asked "Have the ground-water levels in Indiana fallen seriously?" The answer to this question must be qualified. Since settlement of the State began, ground-water levels doubtless have been lowered in many areas, especially where large quantities of water are pumped from wells. In rural areas, generally speaking, the water levels have also declined to some degree because of land drainage, but the decline does not appear to be nearly as great except where formations have been drained by mining or quarrying operations. Where no artificial drainage has been done and where little or no water is pumped, there is no reason to expect that the ground-water levels are any lower now than in the past. Some decline in ground-water levels may be beneficial, as natural losses from ground-water storage through drainage into streams and by evaporation and transpiration are diminished.

In urban and industrial areas, where large quantities of water are pumped from wells, the decline in water levels has been more pronounced, although it is now serious in few places, if any. In the South Bend area, where water levels have declined from 10 to 25 feet during the past 50 years, wells still flow in certain parts of this city.

During the period 1930 through 1944, rainfall in Indiana was generally below normal and ground-water levels declined to probably their lowest stage in history. There has been a general rise in water levels from 1945 to the present time, but when another prolonged period of deficient rainfall occurs, ground-water levels will fall to the low stages once more. It is essential, therefore, to continue our records of water levels in order to be forewarned of possible overdevelopment in areas of heavy pumping or areas of generally scanty supplies.

Studies to date indicate that the ground-water resources of Indiana in general are not being exhausted and additional ground-water supplies may be developed in many areas. Over-all replenishment of the ground-water reservoir is believed to be greater than the withdrawals of water from wells, and large quantities of water are draining naturally into streams. Some of the natural drainage could be salvaged by properly spaced wells.

In heavily developed areas much of the apparent shortage of ground-water supplies is due to the close spacing of wells and their mutual interference, and to incrustation of well screens and of the formations surrounding wells.

The demand for water will continue to increase and ground water will become increasingly important in our daily lives. The inventory of the ground-water resources of the State must be continued to prevent over-development of our present sources and to assist in the development of new sources of supply.

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A New Species of *Atrypa* from the Devonian of Montana

FRANK E. KOTTLOWSKI, Indiana University

The Upper Devonian limestones in the Rocky Mountains contain a species of small brachiopods which has been called *Atrypa missouriensis.* This western species is not *A. missouriensis* Miller as described by Miller (1894, p. 315), Fenton and Fenton (2, p. 15), and Greger (1936, p. 43). G. Arthur Cooper noted (personal communication to Charles Deiss) that "this species of *Atrypa* is not *A. missouriensis* that one can identify by examining D. K. Greger's description of that species. The specimens are very likely a new species which is abundant in the Devonian of Wyoming and Montana." The purpose of this paper, therefore, is to describe the western *A. aff. missouriensis,* differentiate it from the true *A. missouriensis,* and to name the species *A. multicostellata* sp. nov. after the numerous small costellae on the shell.

Atrypa multicostellata sp. nov.

Plate I, figures 1-7.

1877. *Atrypa reticularis,* Meek in King's Rept. U. S. Geol. Expl. 40th Par., vol. IV, p. 38, pl. III, fig. 6a, in Nevada ls fr White Pine, Nevada.

1884. *Atrypa desquamata,* Walcott, U. S. Geol. Survey Mon. VIII, p. 150, pl. XIV, figs. 4-4a, lower horizon of the Devonian ls fr Atrypa Peak, Nevada.

1899. *Atrypa missouriensis,* Girty, U. S. Geol. Survey Mon. 32, pt. 2, p. 502-504, pl. LXVI, figs. 2a-2c. fr. Devonian in Yellowstone Nat. Park.

1908. *Atrypa missouriensis,* Kindle, Bull. Am. Palenthology, vol. 4, no 20, p. 29, pl. 1, figs. 7-7b, in Jefferson limestone near Princeton, Montana.

1940. *Atrypa cf. missouriensis,* Merriam, Geol. Soc. Am., Spec. Paper no. 25, pl. 7, figs. 15-16, in upper Nevada limestone, Nevada.

1947. *Atrypa missouriensis,* Laird, Jour. Paleontology, vol. 21, no. 5, p. 457, pl. 64, figs. 19-22, in lower part of Jefferson limestone in northwestern Montana.

1894. not *Atrypa missouriensis,* Miller, Geol. Survey Indiana, 18th Ann. Rept., p. 315, pl. 9, figs. 19-21, in Callaway limestone near Otterville, Missouri.

Holotype—Indiana University Paleontological Collections, no. 5096. Paratypes: no. 5097, 5098, 5099.

Description—The shell is small, circular to subcircular, with the pedicle beak protruded; the length is slightly greater than or equal to the width. The hinge line is 14° to 35° less than a straight angle and is 80 percent of the maximum width which is at the middle of the shell. The shell is biconvex, its maximum thickness at the umbos; the pedicle valve is larger than the brachial valve and is thickest at the umbo from which the valve slopes gently to the anterior margin but steeply to the lateral margins. The brachial valve is a flat even convex arc although the umbonal region is thick in some specimens.

The pedicle beak protrudes 1½ mm. but is not incurved. The brachial beak is small, slightly incurved, and minutely protruded. The cardinal area is apsacline with respect to the plane of commissure. The pedicle valve cardinal area is small, triangular, 5 mm. wide, 1½ mm. high, and is bounded by minute ventral ridges; the delthyrium is a small triangle under the pedicle beak and is connected to the hinge margin by the pseudodeltidium, which is a small irregular ridge. The brachial cardinal area is minute.

The surface of the valves is covered by 30 to 75 fine costellae which increase by bifurcation anteriorly from the middle of the valves. The costellae average 19 in 5 mm. Growth lines are indistinct and few, or are absent. There is a shallow small medial sinus on the brachial valve posterior to, and on the umbo. On the pedicle valve in the umbonal region there is a small sharp medial fold. A few specimens have 2 to 5 evenly-spaced growth lines, and a wide minute medial sinus on the anterior margin of the pedicle valve.

Dimensions—Length 6 to 16½ mm., average (26 specimens) 10.6 mm.; width 6 to 16½ mm., average 10.3 mm.; thickness 3 to 9½ mm., average (21 specimens) 5.6 mm.; commissure arc averages 254°.

Occurrence—All 42 specimens were collected by Edward D. McKay, Dick S. Horton and the writer in the lower part of the Jefferson limestone (Kottlowski, 4, p. 16, unit 11), 6 miles south of Red Lodge, Montana, in sec. 16, T. 20 N., R. 8 S., Carbon County. The shells were filled in by calcite, most of the internal structures destroyed, and only the prismatic layer, or casts and molds of that layer, preserved. The specimens occurred at all angles to the bedding in a light brown, fine-grained limestone matrix. Fragments and specimens of *A. multicostellata* are abundant in these beds, associated with only a few *Spirifer* fragments.

Comparisons—Miller's figures and descriptions of *A. missouriensis* (1894, p. 315, pl. 9, figs. 19-21) are so general that some writers consider the species unrecognizable. The original specimens, however, were redescribed by Fenton and Fenton (2, p. 15-17) and further collections and a description were made by Greger (3, p. 43-44). The descriptions and figures of Kindle, Merriam, and Laird are of *A. multicostellata*. *A. multicostellata* has smaller and more abundant costellae, 19 in 5 mm. as compared with the 7 to 11 in 5 mm. of *A. missouriensis*. *A. multicostellata* is smaller than *A missouriensis* whose measurements are (Greger 3, p. 44): "length 28 mm.—breadth 33 mm.—thickness 19 mm.". It is not likely that *A. multicostellata* is an immature specimen of *A. mis-*

souriensis as no larger specimens are recorded in the literature than the largest specimens collected near Red Lodge. The Red Lodge collections were made from several localities and not even fragments of larger specimens were observed. *A. missouriensis* has a flatter hinge line that approaches a straight angle; it has stronger and more abundant growth lines; and its width is greater than its length especially for the larger specimens. *A. multicostellata* lacks a wide anterior sinus on the pedicle valve but has a small medial sinus on the umbonal region of its brachial valve; also the pedicle beak of *A. multicostellata* protrudes proportionally further, and is more pointed than the pedicle beak of *A. missouriensis.*

Comparison of Greger's figures (Pl. II, figs. 1-12) of *A. missouriensis* against the figures of Merriam (Pl. I, figs. 8-11), Laird (Pl. I, figs. 12-13) and the specimens from Red Lodge (Pl. I, figs. 1-7) indicate the differences between *A. missouriensis* and *A. multicostellata.*

Stratigraphy—A. multicostellata is abundant in the lower part of the Jefferson limestone in south central Montana and northwestern Wyoming. Laird (1947, p. 453) found the brachiopod in northwestern Montana in his unit Db which he correlates with the lower Jefferson limestone. *A. multicostellata* apparently occurs in the *Spirifer jasperensis* fauna below the middle of the Minnewanka formation in Alberta (Warren 8, p. 133). The Jefferson limestone is considered by Cooper (1, Pl. I) to be of the upper part of the Finger Lakes stage which is lower Upper Devonian (Fig. 1). *A. missouriensis,* however, occurs in the Callaway limestone of Missouri which is of the middle upper part of the Taghanic stage of upper Middle Devonian. Thus *A. missouriensis* appears to occur

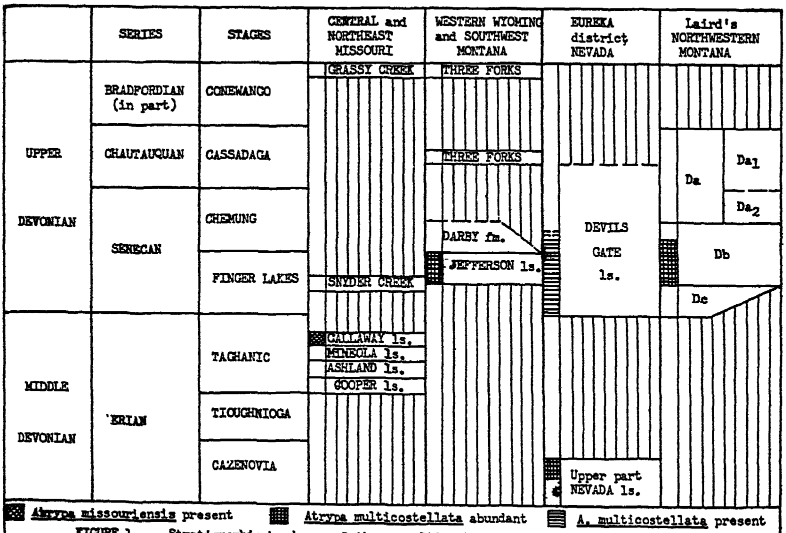

FIGURE 1. - Stratigraphic horizons of Atrypa multicostellata and Atrypa missouriensis. (In part after Cooper, 1942, and Laird, 1947)

only in the midwest and is slightly older than *A. multicostellata* of Montana. Merriam (1940, p. 83), however, found *A. multicostellata* most abundant in the upper part of the Nevada limestone in the *Heliolites* horizon which is correlated by Cooper (1, Pl. I) with the Cazenovia stage of lower Middle Devonian. *A. multicostellata* does persist in Nevada into the Devil's Gate formation which is Upper Devonian. On the basis of *A. multicostellata* the upper part of the Nevada limestone may be Upper Devonian.

Lovering (5, p. 28) noted that the fauna of the Jefferson limestone in the Cooke City district, Montana, is characterized by *A. missouriensis (A. multicostellata ?)* and *Spirifer engelmanni.* Stipp (6, p. 278) collected *Atrypa* aff. *A. missouriensis (A. multicostellata ?)* from the Jefferson limestone in Shoshone Canyon, Wyoming. Tomlinson (7, p. 128) found *A. missouriensis (A. multicostellata ?)* in the Jefferson limestone in western Wyoming and southwest Montana.

Acknowledgments—Professor J. J. Galloway, Indiana University, critically read the paper. George Ringer, Indiana University, photographed the specimens. G. Arthur Cooper, U. S. National Museum, identified the specimens as "a species of *Atrypa* . . . probably a new species which is abundant in the Devonian of Wyoming and Montana."

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Plate I.—ATRYPA MULTICOSTELLATA SP. NOV.

Figure

1- 7. Lower part of Jefferson limestone, near Red Lodge, Montana.
  1. Pedicle view of large specimen.
  2. & 4. Pedicle views.
  3. Pedicle view of holotype.
  5. Pedicle view of small specimen.
  6. Lateral view of holotype.
  7. Posterior view of holotype.

8-11. Devonian unit Db, Pentagon Mountain, Montana (Laird, 1947, pl. 64, figs. 19-22).
  8 & 10. Brachial views.
  9 & 11. Pedicle views.

12-13. Upper Nevada limestone, *Heliolites* horizon, Roberts Mountain, Nevada. (Merriam, 1940, pl. 7, figs. 15-16).
  12. Pedicle view.
  13. Anterior view.

Plate II.—ATRYPA MISSOURIENSIS MILLER

Figure

1- 6. Callaway limestone, east of Otterville, Cooper County, Missouri, on the La Mine River (Greger, 1936, pl. II, figs. 1-6).
  1-3. Views of three pedicle valves.
  4-6. Anterior views of these individuals.

7-12. Callaway limestone, *Spirifer annae* zone, near Bellama Springs, Callaway County, Missouri (Greger, 1936, pl. I, figs. 1, 4, 6, 7, 9, 10.). All pedicle views.

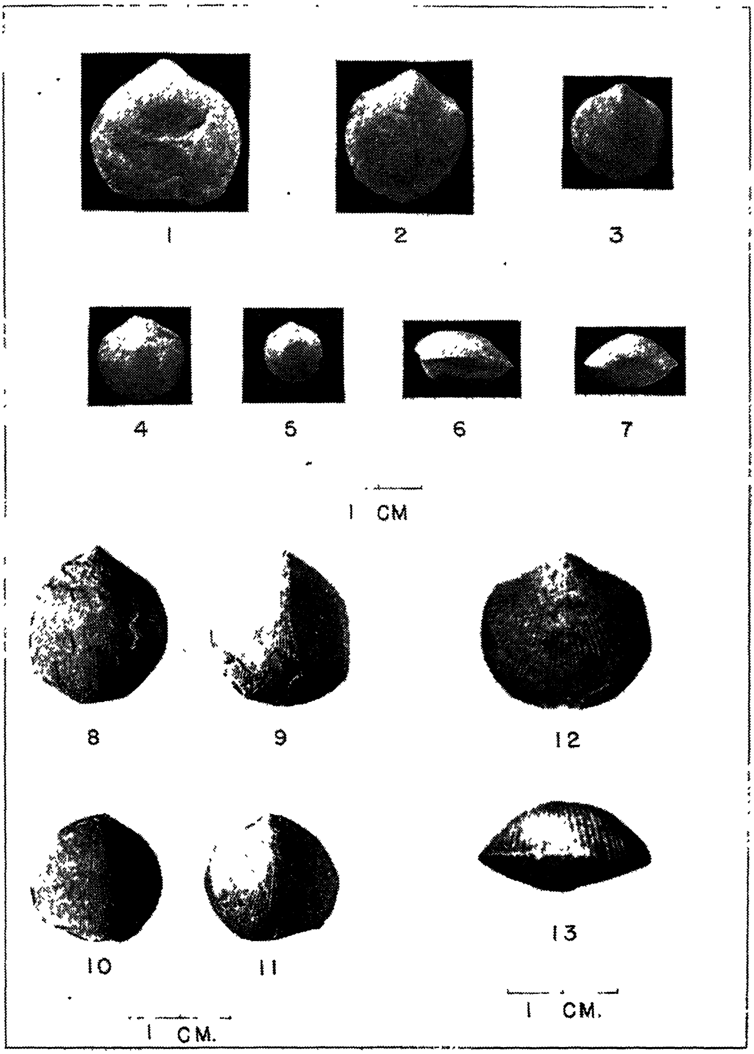

PLATE I

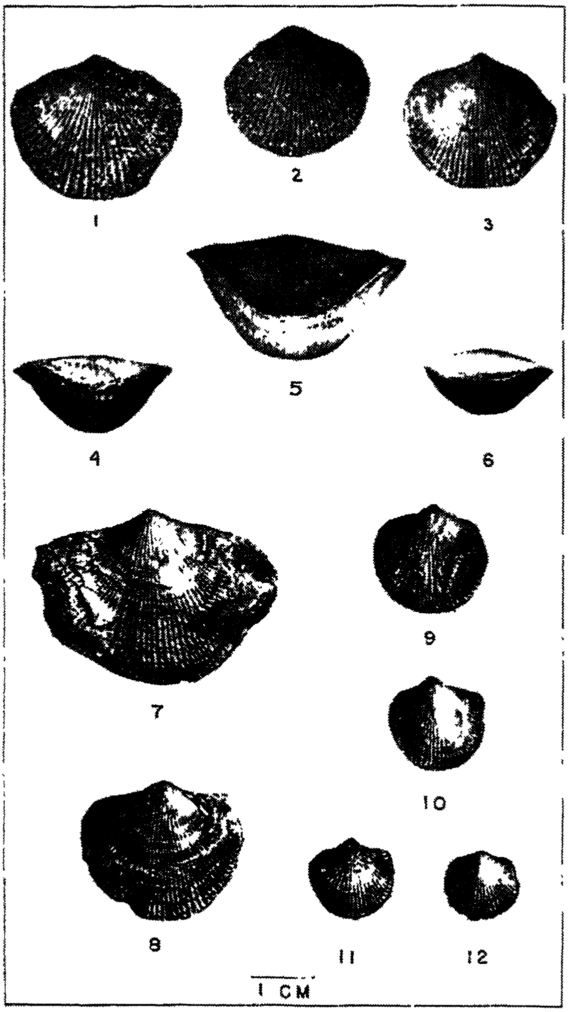

PLATE II

Commerce of Ireland

E. A. STONEMAN, Dept. of Geography, Indiana University

The location of Ireland and its economic dependence on Great Britain did not eliminate the nationalistic feeling of many of the Irish people, nor did it produce unity within Ireland so that eventually partition divided the island into two political units. Created as a diplomatic compromise in 1920 the Republic of Ireland-Northern Ireland boundary separated the six northeast counties of the historical province of Ulster from the remaining counties of Ireland that desired home rule.

Partition has been a subject of dispute since its establishment and political factions in the Republic have been insistent that the boundary be abolished and support their contention by pointing out that the industrial counties of the north would complement the agricultural counties of the south and thus strengthen the economy of the entire island. However, they have been unsuccessful in convincing the majority of the northern people as shown by the 1949 Northern Ireland parliamentary election which voted in favor of partition by a two to one majority.

The boundary has now been in operation for approximately 30 years so that significant trends are now apparent in the internal economy and foreign trade of the two countries. At the time of partition Northern Ireland was considerably more industrialized than the rest of Ireland, a position which she has maintained and increased with the establishment of 157 new industries between 1932 and 1948. Southern Ireland at the time of partition possessed a number of local industries mainly for food processing, while distilleries and breweries provided important exports. Now in an effort for self-sufficiency a number of new industries have been established in the Republic to supply consumer products for the home market. The slogan of "Irish goods for Irishmen," however, is limited by the availability of raw materials making unfeasible the production of many items unless protected by a high tariff, while at the same time technological and engineering skills are not developed to any great extent in several fields. Thus the Republic today remains dependent on imports for many manufactured goods from Great Britain whereas Northern Ireland exports a large amount of her manufactured products to foreign countries.

Although Northern Ireland is much more industrialized than the Republic, agriculture is the dominant occupation in both countries. Northern Ireland's agricultural production is usually at a maximum because of a large local market close at hand as approximately 50% of her population is urban and access to the British market is impeded only by a narrow body of water. During World War II crop acreage was increased to augment food supplies in the United Kingdom, made necessary by the reduction of food imports. The intensification of agricultural production in Northern Ireland was possible due to availability of fertilizers, crop subsidies, and productive labor. A normal surplus of agricultural products over local consumption is shipped mainly to Great Britain which tends to diversify the exports of Northern Ireland. Much of the Republic's soil, depleted during the war by compulsory tillage with insufficient fertilizers, must be rebuilt in order to achieve a higher agricultural production. The shortage of feedstuffs during the war resulted in the reduction of livestock on the farms, but with imported foodstuffs again available their numbers are increasing.

At the end of World War II the Republic looked forward to increased agricultural production, which would make more goods available for export and the expansion of industry by utilizing the sterling balances accumulated during the war to obtain needed materials. Although there has been slight improvement in output and exports since 1945, the British economic crisis and world shortages have slowed progress along these lines. A program to drain or rehabilitate large areas of land suitable for crop production is now under way and should ultimately add considerably to export totals.

Most of the trade between the Republic and Northern Ireland crosses the land boundary, with usually less than 5% seaborne. All railway lines crossing the border are approved for the importation and exportation of merchandise while only sixteen roads of major importance or utility to serve a particular location are designated as approved to serve a border of 228 miles. Local trade across the boundary is apparently declining, although smuggling, the natural result of price differentials between two countries, has been especially prevalent during and since World War II.

Previous to the official establishment earlier this year of the Republic of Ireland, independent of Great Britain, goods entering Northern Ireland from the Republic were subject to the same customs duties as goods arriving from any part of the British Empire and were entitled to preferential treatment. Under the new British trade agreement certain items will retain special consideration and duty rates. Perishable goods from the Republic are not given, on entry into Northern Ireland, any special consideration not accorded similar goods imported from any other country.

Most of the trade between the Republic and Northern Ireland crosses the land boundary, and the peak year according to value for the movement of goods in both directions was in 1924 while from 1933 to 1937 during the Irish Free State-British economic war there was a general decline to almost one-third of the previous total. Imports into Northern Ireland from the Republic were at a high of £9,717,000 in 1924, gradually decreased to a low of £2,711,000 in 1933 followed by a general increase to £9,294,000 in 1947.[1] Likewise the goods entering the Republic were also at an all-time high in 1924 with values at £7,394,000.

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[1] All statistics have been supplied by the Republic of Ireland and Northern Ireland governments.

From 1924 until 1943 these values took a downward trend, with variations, and then started to increase again until reaching £4,236,000 in 1947.

The flow of goods from the Republic to Northern Ireland is always greater than from Northern Ireland to the Republic, sometimes seven and eight times as great. This was especially true during the war years when exports to the Republic declined from the high of 11% of Northern Ireland's total export trade in 1924 to only 1% in 1943. However, since the end of the war these exports by 1947 had increased to 3% of the total export trade between the Republic and Northern Ireland. Likewise, imports from the Republic have declined from the high of 14% of the total import trade in 1924 to 7% in 1933 and although increasing in value from that year have actually decreased to 5% of Northern Ireland's total import trade in 1947. The Republic's imports from Northern Ireland amounted in 1947 to 1.7% of her total trade value; her export trade has increased from 10.6% in 1941 to 19.1% in 1947.

Livestock has consistently been one of the chief commodities sent from the Republic to Northern Ireland, generally amounting to about 50% of the entire total for that one item alone. Food, drink and tobacco formerly were major items but have recently declined considerably. Goods from Northern Ireland to the Republic consist mainly of articles wholly or mainly manufactured.

The value of Northern Ireland's total trade with the Republic although increasing from £10,744,000 in 1944 to £14,179,000 in 1947 has been consistently lower than direct trade with other countries, exclusive of Great Britain, which in the latter year received 86% of Northern Ireland's trade as compared to the Republic's receiving only 5%. Likewise, the Republic in 1947 imported 40% of her goods from Great Britain, a decrease of 30% from 1941, and exported 70% to that country, a decrease of 17% from 1941. The value of total trade in 1947 for Northern Ireland was £302,527,000, 57% greater than the Republic's.

Despite the economic differences in the two countries, both units are dependent upon Great Britain—Northern Ireland for industrial raw materials such as iron, steel and coal, and the Republic for agricultural markets. The value of goods imported by Northern Ireland from and through Great Britain has always been greater than that imported direct from all places outside the United Kingdom and has increased in recent years. Also Northern Ireland's goods exported to Great Britain and other countries via Great Britain are greater than those exported direct to all places outside the United Kingdom. In Northern Ireland the main group of exports were articles wholly or partially manufactured such as linen and rayon goods, cotton goods and machinery. The largest single class of imports into Northern Ireland consists of wholly or mainly manufactured articles, which in the order of their importance for 1946 were machinery, cotton goods, motor cars, woolen goods, papers, etc., amounting to 58% of all materials entering the country.

Except for the recent war period, the Republic's imports are generally much higher than exports, the import surplus being covered by payments of interest on investments held abroad. Irish Sweepstakes receipts, emigrants' remittances, tourist expenditures, and pensions payable by the British government to persons living in the Republic. The Republic's economy is dependent on foreign trade, and the value of its commerce has increased considerably in recent years. Great Britain ordinarily takes over ⅘ of the Republic's exports and supplies more than half of her imports. In the prewar decade the Republic purchased from the United Kingdom such items as coal, tobacco, textiles, and other manufactured goods. Recently the United States has supplied substantial amounts of coal and cereals which normally come from other sources although it is not expected that this will be more than temporary. It is also anticipated that when normal trade with Great Britain is resumed, amounts will be comparable to prewar figures.

Normally almost 70% of the Republic's imports are composed of raw materials and manufactured goods, and approximately 30% of live animals, food, drink and tobacco. The export of live animals in the Republic, except for the year 1941 when they were restricted because of the hoof and mouth disease, leads in total value—almost ⅗ of the total exports of 1947 and slightly over half of those of 1939.

At the present time the removal of partition would probably not increase appreciably the total trade between the six counties and the rest of Ireland except in local areas and for a limited number of items. Without the use of protective tariffs for the whole island, which would increase the cost of the items, British and other foreign competition would be too keen. Some manufactured goods would enter the Republic from Northern Ireland but many products would still originate in Britain, and the market for all of Ireland would not support some types of heavy and machine tool industries. The Republic is dependent upon Great Britain for an agricultural market and lacks the diversification characteristic of Northern Ireland's exports. Both the Republic and Northern Ireland depend upon Great Britain for their coal while the latter must also obtain iron and steel supplies to maintain her large ship-building industries; therefore, the principal trade of both countries would still be oriented to Great Britain.

Thus irrespective of the Republic's attempt to become politically and economically independent, her economy and that of Northern Ireland are tied closely to that of Great Britain and apparently will remain so in the immediate predictable future.

Indiana Thunderstorms

STEPHEN S. VISHER, Indiana University

Thunderstorms occur during about 50 days annually in each part of central Indiana, in about 45 days in northeastern Indiana and in about 55 days in the State's southwestern corner. During the summer, each locality normally has thunderstorms in about two days per week. In about ten days per year, mostly in summer, two thunderstorms occur, one in the afternoon and one at night. Lightning from distant storms, too far away to have appreciable local significance, may be visible on one or two additional nights per week in summer. Most thunderstorms cover only about one-fourth of the state and many of them cover less than a sixth of it. Hence it is probable that fully 200 individual thunderstorms occur per average year in Indiana.

Thunderstorms are such a significant environmental influence in Indiana that it is highly desirable that more of the State's leaders be well informed about them. Increased knowledge facilitates, of course, greater appreciation and wiser adjustments.

Thunderstorms are significant in several respects. They form a major source of rainfall, cause a sharp drop in temperature, commonly have at least a little strong wind; their most distinctive feature is thunder, induced by lightning. Their cloud effects are noteworthy, some of the most imposingly beautiful seen anywhere. They often yield hail as well as rain. Altogether they are perhaps the most impressive atmospheric phenomenon commonly seen, highly useful in the aggregate, but locally often seriously harmful. The good they do, aside from the rain they bring, which often is highly welcome, includes the invigorating drop in temperature, the awe-inspiring display of cloud, lightning and wind, and the generally stimulating effect of the dramatic change of weather. The harm they do includes the squall wind, generally just before the rain commences. This gust often is violent enough to do considerable damage. The annual average property loss from thunderstorm squall winds in Indiana is officially estimated at about $400,000. Rain often falls torrentially, with the result that a large share of that which falls upon sloping ground runs away. Much of the soil erosion of our fields is due to thunderstorm rain. "Cloudbursts" not only cause erosion but they sometimes produce locally harmful floods. The lightning incidental to thunderstorms affords a spectacular display of usually harmless fireworks but also often does damage. Each average year seven people are killed by lightning in Indiana. Many thousand livestock are also killed, apparently an average of more than 4000 hogs and 1000 cattle and numerous horses. Fires started by lightning annually destroy buildings worth about a half million dollars in Indiana, and some crops. The lightning of thunderstorms does good as well as harm. Every flash combines some atmospheric nitrogen and oxygen to form ammonia, which when carried into the soil by rain adds fertility. This is an important source of increased fertility. At the few stations in northeastern United States where prolonged studies of this subject have been made, six to eight pounds per acre per year are added thus. Lightning flashes also create ozone, an unstable form of three oxygen atoms (O_3). Ozone has a pungent odor; some evidence indicates that it has a stimulating influence upon mental activity.

Lightning is most dangerous at the beginning of the storm, just after the squall wind, when many lightning flashes travel downward. Later, lightning commonly is between parts of the storm or even upward from the ground.

Hail which falls in many thunderstorms is a convincing proof that the air is cold overhead even in hot weather. It also proves that the updrafts of air which make the imposing thunderhead are strong. Hail does considerable damage in Indiana, where there are an average of about 5 "heavy" hailstorms each season and a like number of "moderately heavy" hailstorms. Indiana's hailstorms cause an estimated average damage to crops and glass somewhat in excess of $1,000,000 per year.

The average thunderstorm in Indiana yields somewhat more than a half inch of rain, but many yield an inch and some yield more than three inches. Indeed, rarely, a "cloudburst" may yield more than 5 inches. Rainfalls of more than 2 inches in an hour are almost sure to cause considerable local flooding in Indiana, and serious soil erosion on cultivated slopes.

The value of the rainfall yielded by thunderstorms depends, of course, on when it comes. If, as frequently happens, it comes when it is badly needed, a single thunderstorm may locally increase the yield of corn to the extent of several thousand dollars per square mile. For example, in late August, 1947, when this paper was being completed, the drouth in Indiana was reducing each day the prospective corn crop an estimated million bushels. A "good" thunderstorm in the critical period of corn growth, following a prolonged dry, hot spell, increases the average per acre yield in its area at least several bushels per acre, and therefore is worth more than $1,000,000.

About half of Indiana's summer thunderstorms occur in the afternoon (noon to 6 P.M. local time). Afternoon thunderstorms are somewhat more characteristic of southeastern Indiana than of northwestern.

About one-fourth of Indiana's summer thunderstorms occur between 6 P.M. and midnight, local time. Evening thunderstorms are somewhat more characteristic of northwestern Indiana than of southeastern.

The half-day, midnight to noon, has somewhat less than one quarter of the thunderstorms in Indiana. Very few occur in the forenoon, more occur shortly before dawn.

June is the month of most thunderstorms in the western half of Indiana while July has most in the eastern half. Thus in central Indiana the last week in June or the first week in July are those of most thunderstorms.

Hail always occurs in thunderstorms in Indiana, but only about one-tenth of the thunderstorms yield damaging amounts of hail. Hail storms are most frequent, however, somewhat earlier than the month of most thunderstorms. May has had most hailstorms in most of Indiana but along the eastern margin of the State, hail is somewhat more frequent in April than in May.

Tornadoes are also always associated with thunderstorms. Like hailstorms, they are most numerous, however, before the month of most thunderstorms. In Indiana, May has most tornadoes except at the extreme south, where March or April has more tornadoes than May.

(Additional data on Indiana's lightning, hail, tornadoes and squalls may be found in "Climate of Indiana" but this article notably supplements the discussion in that volume of thunderstorms.)

Summary and Conclusions

Indiana has thunderstorms on about 50 days per average year, of which about ten days have two. As most of the thunderstorms cover only about a fourth of the State, about 200 individual thunderstorms per average year occur in Indiana. About half of them occur in the afternoon and a quarter between 6 p.m. and midnight. About half of the year's total occur in summer, when each locality normally has two or three per normal week. Thunderstorms are the major source of summer rain and are significant in several additional respects. They cause an often welcome cooling, and impressively beautiful displays of cloud and lightning. They also often cause considerable damage by their lightning, hail, squalls and "cloudbursts". In an average year the lightning kills 7 people in Indiana, burns buildings and crops and kills farm animals worth an aggregate of about $500,000; the hail causes an estimated annual million dollars of damage to crops and glass; the squall winds damage buildings to the extent of an annual average of $400,000. The erosion of cultivated slopes and the occasional local flooding also cause sizeable losses. But the good that the rain does generally much more than offsets the damage caused in these other ways. If proper care is taken as to lightning rods and hillside land use, the losses can be much reduced. Following hot dry spells, a single thunderstorm may increase crop yields by more than a million dollars. Without thunderstorms, Indiana would necessarily be a third rate agricultural state despite its several other advantages, and would also be much less desirable for industry in various other respects. Therefore it behooves us to appreciate them and make appropriate adjustments.

A Karst Valley in Western Monroe County, Indiana

WILLIAM J. WAYNE, Indiana University

The name karst has been applied to regions which are underlain by limestone, and which possess a topography due to underground solution by meteoric waters and diversion of surface drainage through these underground channels. The term is taken from a plateau in Jugoslavia bordering the Adriatic Sea, upon which a vast number of solution features have been studied. This area is underlain principally by limestone beds of Mesozoic and Cenozoic age. The entire plateau possesses rather high relief, and has undergone considerable folding and faulting, which in itself can cause a region to have unique topography. Solutional activity in such an area can cause landforms to occur which may not necessarily be characteristic of karst in other regions possessing lower relief and structure.

The physiographic forms discussed in this presentation are typical of relatively flat limestone regions such as those found in the Mississippi valley.

A karst plain or sinkhole plain is a region underlain by limestone in which all the drainage is underground, and sinkholes form the principal relief, taking up much of the upland area. Seldom do any but large streams succeed in crossing karst plains without sinking underground.

A karst valley is a valley in which karst features have developed in a valley floor to such an extent that the stream no longer carries surface drainage except in periods of excessive rainfall. Only the valley floor exhibits karst features however; the slopes and uplands are usually capped by clastic sediments in which solution is of little importance.

As a stream erodes through clastics and uncovers a limestone bed, some of the water is diverted downward through the joint system of the limestone, and solution of the calcium carbonate starts. As the openings along the joints and bedding planes increase in size, they are capable of diverting more and more of the surface drainage into underground channels. When swallow-holes along the course of a stream are able to take the entire volume of runoff, the stream channel becomes a dry-bed, carrying only stormwaters. This condition is a common occurrence at the top of the upper Mississippian limestones, along the western edge of the outcrop of upper Mississippian rocks in Indiana and Kentucky. (Malott, 3).

It is the purpose of this paper to describe a karst valley located in western Monroe County, Indiana, about 7 miles southwest of Bloomington, Indiana (Fig. 1). This particular region has been referred to by Beede (1), who noted the case of subterranean piracy of the headwaters of Indian Creek by Richland and Clear Creeks.

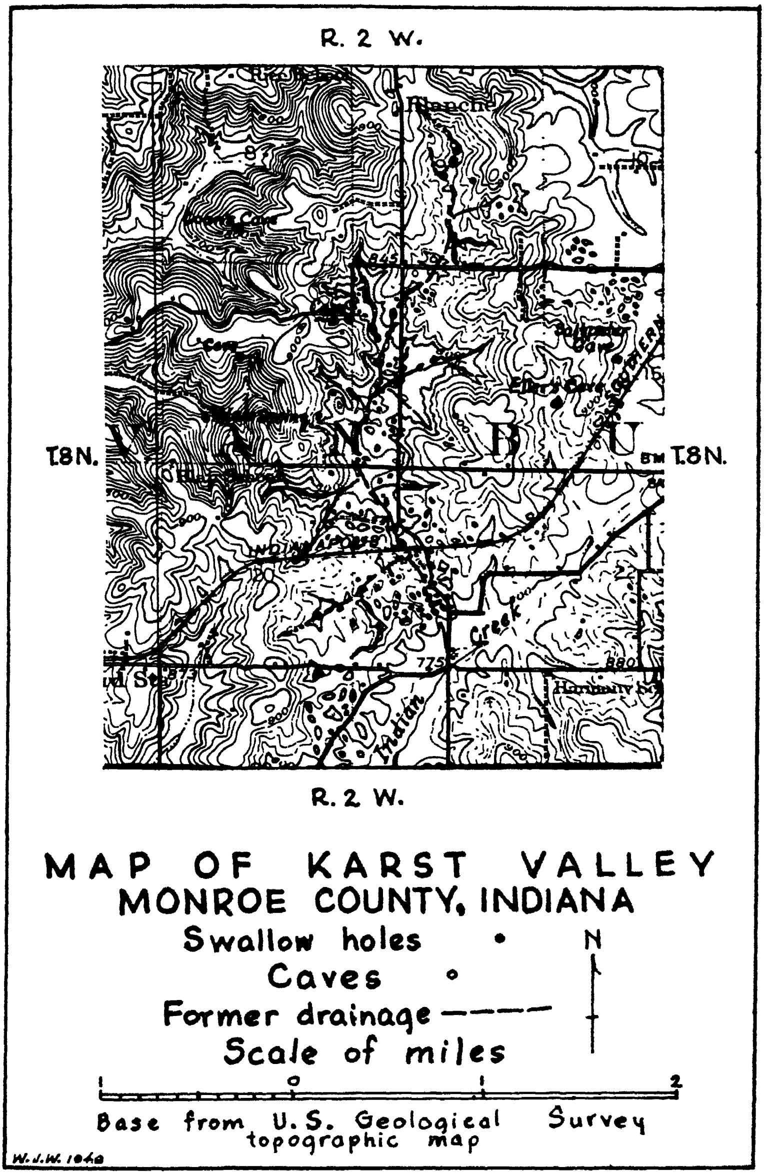

Fig. 1. Map of the karst valley south of Blanche, showing the probable restored drainage and with the major dry-beds and swallow-holes indicated (Base from the U. S. Geological Survey topographic map of the Bloomington, Indiana quadrangle.)

In the stratigraphic setting of the area under discussion, the Ste. Genevieve formation, a dense, jointed limestone of middle Mississippian age immediately underlies the mantle rock in the western part of the Mitchell Plain. The majority of the sinkholes in the bottom of the valley are found in this formation. Overlying it are the members of the lower part of the Chester series. The lowest of these is the Aux Vases sandstone, a bed about one foot thick here, which is seldom exposed. Above it is the Paoli limestone, a somewhat oölitic limestone about 15 to 20 feet thick. Karst features show extensive development in this limestone, and continue downward into the thicker Ste.Genevieve formation. The first of the Chester clastics of any thickness is the Mooretown sandstone and shale, which caps many of the lower hills. It is about 20 feet in thickness. Overlying the Mooretown sandstone and shale is a thin limestone generally about 15 feet in thickness called the Beaver Bend limestone. Occasionally a few sinkholes are found on its outcrop, but it is not sufficiently thick for extensive underground drainage to

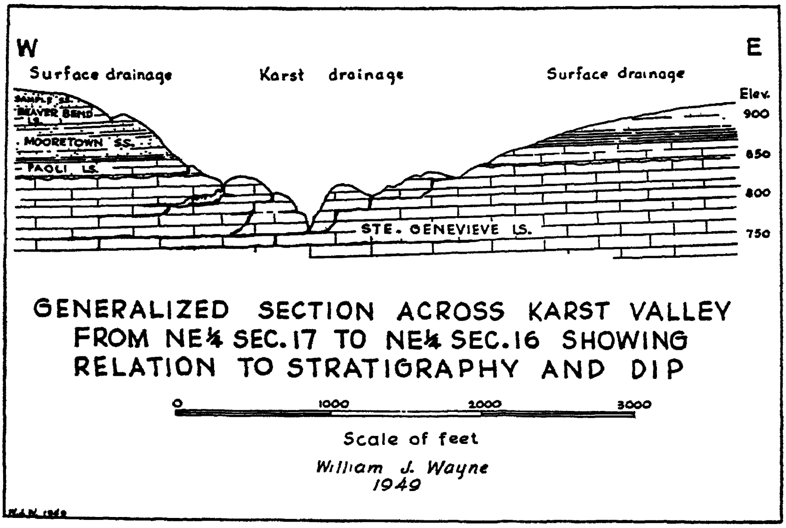

Figure 2. Generalized east-west section across the karst valley at a place about 1 mile south of Blanche, showing relationships of the karsted area to the underlying rock and the regional dip.

develop. The Sample shale and sandstone, overlain by the Elwren sandstone caps the higher hills of the region. In only a few places can the Reelsville limestone be found between the two, since in many places it has been removed completely by solution. Figure 2 shows the relationships of the karst valley to its stratigraphic setting.

Much of the former headwater region of Indian Creek, in T. 8 N., R. 2 W. is now drained by subterranean streams rather than by surface runoff. The Mitchell Plain west of Bloomington is pock-marked by numerous sinkholes. Some of the water entering the ground in this area emerges in springs west of the Chester escarpment. One of the largest of these is Blair Spring, northeast of Blair School, in the S. W. quarter of sec. 17, T. 8 N., R. 2 W. When the streams flowing across the clastic rocks of the upland encounter the jointed dense limestone beds that characterize the karst plain they become pirated by subterranean drainage. As more and more of the drainage goes underground, the stream ceases to carry any water over its course except during storms. Such is the case of the small southward tributary of Indian Creek heading at Blanche.

The valley south of Blanche was developed along the strike of the westward dipping rocks of the Crawford Upland, probably sometime previous to the late Tertiary peneplanation of the region, and was eroded downward until it reached the limestones of the lower Chester and upper Meremec series. The downcutting may have reached the soluble limestone prior to peneplanation or afterward, but shortly after the region was rejuvenated, the runoff waters from the surrounding hillsides began to disappear into swallow-holes along the stream channel until the entire normal volume of the stream had been pirated by subterranean channels. As the disruption of the normal surface drainage began near where the valley enters that of Indian Creek, the solution action has had more time to operate there than further upstream, and the former stream channel has been entirely obliterated. By careful examination of topographic maps, the former surface drainage system of the area can be approximated (Malott, 2, pp. 199-200).

The lower part of the karst valley in the vicinity of the Illinois Central Railroad is about one-half mile wide, and the floor of the valley appears nearly level. It is pock-marked with sinkholes, many of them compound. Sinkholes of both simple solution and collapse types are present, although the latter are few in number. Frequently sinkhole outlets are so tightly silted shut that the depressions hold water.

Upstream a ridge crosses the valley transversely in the S. half of N. W. quarter of sec 16, T. 8 N., R. 2 W. This ridge appears to have been a portion of the valley floor at the time of sinking, but undoubtedly has been lowered somewhat by solution. On the north side of this ridge there are several large swallow-holes, two of which have visible openings in the bottom. One of these is a deep conical depression with a hole in the bottom into which stormwaters pour. A raft of tree limbs usually fills the bottom of the pit. The opening apparently takes a great volume of water quite rapidly, as no flooding of the pit has been observed due to choking of the subterranean channels.

In the blind valley which ends at this point, the flood waters course over a dry bed incised 10 to 15 feet below the surrounding valley. There are several small swallow-holes present along the dry bed, each of which takes up some of the stormwaters. During a heavy rain, muddy water as much as three feet deep rushes along the stream. Each opening takes some of the water, but most of it pours into the large terminal swallow-hole. A few hours following a rain, the dry bed is completely drained.

The portion of the valley in sec. 9, T. 8 N., R. 2 W. is completely dismembered, but it has been so recently karsted that the former channel can be followed along a series of sinkholes. There is little surface drainage, and no dry bed is present, but a long shallow depression with a swampy area in the middle takes the water coming off the gullies on the sides of the valley. A large swallow-hole a short distance north of a gravel road along the south edge of sec. 9 intercepts the drainage down two westward flowing ravines before it reaches the center of the valley. A similar sinkhole, although frequently much smaller, is found at the end of every gully running down the side of the valley.

The area in the center of the section one-half mile southeast of Blanche shows the last stages of recognizable surface drainage before complete disappearance of the former channel. The valley is a chain of funnel-shaped sinkholes strung together by a shallow dry bed that is completely overgrown with vegetation. A small dry bed coming from the west at this place loses itself completely into a shallow swallow-hole just before reaching the center of the karsted valley.

A small gully heading at Blanche tumbles as an intermittent stream over sandstone and shale until entering the limestone outcrop. About 500 yards below its head the creek enters a large flat-bottomed sinkhole into which it disappears. Over the alluviated floor of the sink at least five deep conical holes swallow stormwaters. The floor of the sink is littered with rafted debris and a mat of tree branches covers each of the holes.

Surface drainage on the sides of the karsted valley is quite evident in many places, as gullying has occurred since the land was cleared. Badland topography has not formed to the extent found farther westward, but at several places gullies 3 to 4 feet deep expose weathered shale.

It would be interesting to explore the subterranean route followed by the waters diverted downward into enlarged passages along the joints and bedding planes of the limestone. Several openings are present in the valley large enough to admit a man, but only one of these has been entered and explored by the writer. This one is a small cavern in the N. E. quarter of sec. 17, T. 8 N., R. 2 W. Other holes that appear to be possible entrances to a portion of the hidden cavern system are one in the bottom of the main swallow-hole in the N. W. quarter of sec. 16, and a nearly vertical tubular channel about two feet in diameter in a small sinkhole southwest of Blanche, in the N. W. of the S. E. quarter of sec. 9.

The entrance of the cave which was in part explored is in an insignificant looking sinkhole perched on the side of the valley. A vertical hole in the ground about 10 feet deep enters on a narrow leaf-strewn platform. This platform is about 10 feet above the floor of a cavernous room. The size of this chamber, as well as the opening to the surface appear to be due in great part to collapse and stoping. The floor of the room is partially alluviated, and during a storm carries the water from the surrounding sinkholes.

Two openings, both about 2 feet high and 6 to 8 feet wide lead out from the first room. One of these, toward the southeast, appeared to get smaller and was not followed. The other has a dry silt floor, and after about 50 feet opens into a cavern through which one can easily walk erect. Dripstone features in this portion of the cavern are quite abundant, and collapse is taking place along the cavern roof. Pebbles in several pools into which water drips are coated with calcium carbonate. A hole is present in the cave floor in which one can obtain a glimpse of a more active section of the cave.

The caverns which carry the underground streams at the present time are undoubtedly quite youthful. Only a few opportunities have presented themselves to view much of this cavern system. Those portions no longer used by the phreatic waters have begun to collapse, but beneath them are many tubes through which the unseen subterranean streams course.

This valley shows the first stages in the encroachment of a karst terrane upon a non-soluble upland. Above the limestone floor of the karsted valley, gullies tributary to the former drainage end in sinkholes. Many of the forms typical of a karst region are already well under way in their development. Erosion will eventually lower the divide on the eastern side of the valley, and the escarpment separating the two physiographic areas will be farther west.

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MATHEMATICS

Chairman: PAUL OVERMAN, Purdue University

W. H. Carnahan, Purdue University, was elected chairman for 1950.

ABSTRACTS

Sampling Distribution for Medians from a certain general Population. I. W. BURR, Purdue University.—Given the cumulative frequency function $F(x)=1-1/(1+X^c)^k$, the exact sampling distribution of the medians, Z, for a sample of $N=2n+1$ cases is:

$$\frac{N!}{(n!)^2}\left[1-\frac{1}{(1+z^c)^k}\right]^n \frac{ck\,Z^{c-1}}{(1+z^c)^{nk+k+1}}$$

Moments are readily obtained and it is possible to compare the efficiency of the mean and median for strongly skewed and J-shaped frequency curves as well as more "normal" ones.

Einstein's proof of the equivalence of mass and energy. WALTER H. CARNAHAN, Purdue University.—Making use of two well-known laws from elementary physics and high school algebra Einstein established the formula $E=mc^2$ as the equivalence relation between mass and energy. The paper reviewed the steps in Einstein's development, giving full details so that any person with only a good high school education could follow the reasoning.

Note on the solution of the special case of the non-homogeneous first order and first degree differential equation by means of an integrating factor. WILL E. EDINGTON, DePauw University.—The solution of the special case of the non-homogeneous first order and first degree differential equation by means of an integrating factor is of interest pedagogically because this equation is no longer considered as an exceptional case requiring special methods of solution·

Solution of

$$X^2\frac{d^2y}{dx^2}+KX\frac{dy}{dx}+(X^2-n^2)y=0$$

in terms of Bessel functions. ROBERT R. HARE, Indiana University.—The solution of the differential equation

$$X^2\frac{d^2y}{dx^2}+KX\frac{dy}{dx}+(X^2-n^2)y=0,$$

k and n being constant real values, may be expressed in terms of Bessel functions as

$$y=X^{(I-K)/2}[C_1J_q(X)+C_2J_{-q}(X)]$$

when q is not an integer, and

$$y=X^{(I-K)/2}[C_1J_q(X)+C_3Y_q(X)$$

when q is an integer. q is defined as $\sqrt{}(K-I)^2+4n^2/2$; $J_q(X)$, $J_{-q}(X)$, and $Y_q(X)$ are Bessel Functions; C_1, C_2, and C_3 are arbitrary constants.

The differential equation is transformed into the Bessel equation

$$X^2\frac{d^2u}{dx^2}+X\frac{du}{dx}+(X^2-q^2)u=0$$

by means of the substitution $y=ux^{(I-K)/2}$, where q is defined as above.

Mathematics in present day Europe. DR. J. KOREVAAR, Purdue University.—The War has given a great impetus to the study of Applied Mathematics in Europe. Governments are eager to subsidize research in this particular field. This paper perhaps deals more with the situation in Holland than is consistent with Holland's significance, but on the other hand the development in Holland since the war is typical for many countries in Europe.

An Experiment in Sampling from a Pearson Type III Distribution. LOIS JEAN NIEMANN.—Samples of four were taken from a Pearson Type III population of $\alpha_3=1.1$. Distributions of the means, medians, standard deviations, mean deviations, and ranges of the samples were compared with those from a normal population. Also calculated were eight correlations between the above mentioned statistics.

The Epistemic Correlation. J. CRAWFORD POLLEY, Wabash College.—A discussion of mathematical induction and the total differential equation as illustrative of F. C. S. Northrop's theory on knowledge. The author shows how the two mathematical theories may be so interpreted as to satisfy the conditions relative to what Northrop calls the "aesthetic component" and the "theoretic component" of knowledge, and the "epistemic correlation" which connects them.

The History of Calculus. ARTHUR ROSENTHAL, Purdue University.—This lecture discusses the development of the ideas leading to Calculus, from Archimedes to Newton and Leibniz, and in particular the role of the predecessors of Newton and Leibniz.

PHYSICS

Chairman: A. R. THOMAS, Valparaiso University

D. Roller, Wabash College, was elected chairman for 1950.

ABSTRACTS

An Electronic Hydrogen Detector. L. W. AUCKERMAN, Purdue University.—In designing the Purdue cryogenic laboratory one room was reserved for experiments using liquid hydrogen. Though every feasible safety precaution was taken, it was considered desirable to construct a dependable device for giving a continuous indication of the air hydrogen content and which would set off an alarm if the concentration should rise above a certain predetermined level.

For this purpose a wheatstone bridge in conjunction with suitable electronic circuits is utilized in such a way as to detect an increase in thermal conductivity of the air. An increase of hydrogen content will increase the thermal conductivity of the air and will consequently produce and unbalance of the bridge. The output of the bridge is amplified, rectified, and, if above the critical value, is used to trigger an electronic circuit which in turn excites a relay. This relay then turns on a warning device.

The circuit also employs a meter which is calibrated directly in percentage of hydrogen. The point at which the triggering mechanism excites the relay is adjustable: two per cent hydrogen by volume is considered a satisfactory setting since four per cent is the explosive limit. This particular circuit is capable of detecting as low as one per cent hydrogen; however, it is quite probable that with greater design precautions one could go as low as 0.1 per cent.

Beta Spectrum of Pr^{143}. J. A. BRUNER, L. M. LANGER, D. MOFFAT, Indiana University.—The beta spectrum of Pr^{143} (13.8 d) has been studied in the 40 cm. radius of curvature shaped magnetic field spectrometer and also in a smaller version employing a 15 cm. radius of curvature. Although the comparative half life (ft $\sim$ 4.5×10^7) indicates that the transition is once forbidden, the spectrum was found to have the allowed shape. This suggests that the spin change must be less than 2. In order to satisfy these conditions it is necessary that, in this case, the $2d_{5/2}$ and $1g_{7/2}$ states be inverted in the nuclear shell model of M. G. Mayer.[1] The end point was found to be 0.922±0.003 Mev.

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[1] M G. Mayer, Phys Rev. **75**, 1969, 1949.

Shape of the interference fringes obtained with the Michelson-Williams reflection echelon. DELMAR O. DAVIS and K. W. MEISSNER, Purdue University.—The shape of the interference patterns which one has to expect when a Michelson-Williams reflection echelon is equipped with a long collimator slit, has previously been derived and discussed by K. W. Meissner. In order to check these results the reflection echelon of Purdue University was set up in an autocollimation arrangement. By employing a long slit, illuminated with the green krypton line 5570A, several photographs were obtained which exhibit the special features to be expected according to the calculations mentioned above.

A method for determining short time stress-rupture characteristics of various steels. W. E. FONTAINE, J. E. BROCK, and SAMUEL TARSON, Purdue University.—A method is described by which small specimens of steel may be stressed in an atmosphere of steam at 1200°F until rupture occurs. Stresses are chosen so that rupture occurs in less than 100 hours. Short time stress-rupture curves are shown for three different types of steel.

The Photoelectric Light Curve of the Eclipsing Star YY Canis Minoris. H. HAROLD HARTZLER, Goshen College.—Two hundred and forty one photometric observations were made of this star at the Steward Observatory of the University of Arizona from February 21, 1949, to April 24, 1949. Each observation consisted of a two minute observation on a comparison star, then a four minute observation on the star being measured and a final two minute observation on the comparison star. The light from the star was concentrated by a thirty six inch telescope on a photoelectric cell and then, after suitable amplification, automatically recorded by a Leeds and Northrup micrimax recorder. Five times of primary minimum were observed.and a new period of 1.0940232 days was computed. The magnitude of this star changes from 8.5 to 9.4 in a periodic manner. Its spectral type is F5. The light curve of the star will be shown.

The stopping of fast deuterons in semiconductors. Z. H. HELLER and D. J. TENDAM, Purdue University.—Measurements of the stopping power of Ge and Si, as proposed by K. Lark-Horovitz, have been made for use in evaluating experiments on the nuclear bombardment of semiconductors, and to obtain information about the stopping process in these materials.

The reduction in range, due to the absorber samples, of the deuteron beam from the cyclotron (9-10 MeV) was measured using a system of two ionization chambers, one fixed and one movable, and a suitable detecting circuit. Curves for the conversion of extrapolated ionization ranges (which were measured) to mean number ranges were computed for large straggling parameters.

The stopping powers found were:

$2.18 \text{ mg/cm}^2 \text{ Ge} = 1 \text{ cm air}$

$1.50 \text{ mg/cm}^2 \text{ Si} = 1 \text{ cm air}$

The stopping power of Ge showed negligible velocity dependence when the incident beam energy was reduced.

Curves of range reduction vs. absorber thickness were measured for Al, Ni, Cu, Zr, Rh, Ag, Sn, and Au in order to compare the semi-conductor stopping powers with those of the metals. No significant difference was found. The figures for the metals also showed that the stopping powers in Table XLIX of the Livingston and Bethe[1] article need modification, the velocity dependence being accurate but the values some 3-6% too low.

Electrical Behavior of Semi-conductors at Very Low Temperatures. C. S. HUNG, P. H. KEESOM, and K. LARK-HOROVITZ, Purdue University.—Using special cryostats to measure the electrical resistivity and Hall effect through the temperature range from room temperature to liquid helium temperature, Germanium, Silicon and Tellurium semi-conductors have been investigated. For some Germanium and Silicon semi-conductors with a large number of impurity centers so as to give the degenerate behavior as predicted by the theory of Johnson and Lark-Horovitz, theory and experiment agree. Some Silicon samples show a behavior which indicates, as has already been found at higher temperatures, that the resistance is due in part only to impurity scattering and lattice scattering and is due in a large extent to grain-boundary scatterings. Purest Germanium single crystals show anomalous behavior in the low temperature range, indicating, perhaps, inhomogenieties which are not detectable at room temperature. For these samples the assumptions usually made in the derivation of the Hall effect are not fulfilled. A similar effect is also observed in Tellurium; whereas at ordinary temperature Tellurium does not show any measurable dependence of Hall effect on magnetic field, such a dependence can be observed in the low temperature range.

Crystallization of Rubber. HUBERT M. JAMES, Purdue University.—The freezing of rubber is a relatively complex phenomenon. Rubber freezes slowly at temperatures between —50°C and +15°C, most rapidly at about —25°C. The melting point is also variable, depending on the temperature of freezing and on the length of time the material has remained frozen. Rapid freezing can be brought about by stretching the rubber, even at temperatures above 100°C; again the behavior of the frozen rubber depends on the conditions under which it was frozen. These peculiarities of rubber arise from its structure as a molecular network. The rate of freezing depends, as with any material, on the rate of formation and growth of crystal nuclei; in rubber, however, there is the added factor that growth of any single crystallite is limited by the network structure. The molecules in rubber crystals are not equivalent, as in ordinary crystals, but are subject to differing constraints due to

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[1] M. S. Livingston and H. A. Bethe, Rev. Mod. Phys. 9, 261 (1937).

their different positions in the network. The melting point of the crystals depends on the disruption forces exerted on them by the network; these are greater the more rapidly the crystals are formed. Stretching rubber favors crystallization by aligning the molecular segments and decreasing the entropy change on freezing; it also favors the formation of crystals which, in the unstretched material, will be subject to large disruptive forces.

Theory of the Hall effect at very low temperatures. V. A. JOHNSON and K. LARK-HOROVITZ, Purdue University.—In the study of semi-conductors, one obtains information about n, the number of free electrons (or holes) per unit volume in a sample, by measuring the Hall coefficient R. As long as current carriers of only one sign are present in the sample, R and n are taken to be related by the equation: $R=3\pi/(8ne)$. Recent studies at Purdue show that there is good basis for doubting the validity of this equation at very low temperatures, especially in the range 1°K.-40°K. One important source of error lies in an assumption made in deriving the equation, i.e., that the mean free path of a free electron does not depend upon the energy of an electron but only upon the temperature of the sample. It has been found that this assumption is not valid at low temperatures and produces a 10% error at 50°K, a 40% error at 15°K, and still greater errors at lower temperatures. A second source of error appears whenever the mean-free-path is comparable in magnitude with the radius of curvature of the electron path in the magnetic field. Since the mean-free-path increases at 1/T as the temperature drops, while the radius decreases as $T^{1/2}$, the two distances approach equality at very low temperatures instead of the radius being about 100 times larger, as is the case in near room temperature.

The performance of the Purdue linear electron accelerator. JOHN W. MACKAY, Purdue University.—The accelerator consists of a cylindrical resonant cavity 1 meter long, excited by a 1 megawatt 10 cm. pulsed magnetron. Pulses of electrons are injected with an initial energy of 300 Kev. The output of the accelerator is analyzed with a magnetic spectrograph. Pulse techniques are used to observe the output current. Numerical integration of the electron orbits through the accelerator indicates that the energy spectrum should contain three peaks between 1.0 and 1.4 Mev. According to theory the electrons making up one of these peaks should suffer large radial forces in the accelerator and be widely spread in cross section. A second peak should be somewhat defocussed and the third only slightly defocussed. Analysis of the emergent beam shows two of these peaks and their distribution in the cross section of the beam. The electrons forming the other peak are apparently too widely spread to be detected.

Influence of irradiation on the voltage-current characteristic of a glow discharge through rare gases. K. W. MEISSNER and R. M. PIERSON, Purdue University.—When the positive column of a gaseous discharge through a very pure rare gas is irradiated with light from another discharge tube containing the same rare gas one observes a distinct change of the current and of the voltage across the irradiated discharge tube. Experiments were carried out with neon and helium discharge tubes at various pressures. These experiments establish the fact that the voltage-current characteristics of these discharges are raised by irradiation. This effect can be understood by considering the role of metastable atoms in discharges through rare gases and that their number can be appreciably decreased by irradiation of light of proper wave length.

Some characteristics of the scintillation counter. MAURICE M. MILLER, and WALDO RALL, Indiana University.—Two 1P28 photomultiplier tubes were used in coincidence as a scintillation counter with low noise background. The performance of this counter as a proportional beta counter was investigated. A commercial electron gun, mounted in a vacuum system, was used to accelerate electrons up to 5600 volts. The gun was operated to give a beam current ranging between 10^{-10} and 10^{-12} amperes. The phototubes were operated at —600 volts. Integral bias curves were obtained which are logarithmic over three orders of magnitude. Curves will be shown giving pulse height distribution and efficiencies from 500 to 5600 volts. The relative efficiency of the scintillation counter as a gamma detector is now being investigated by means of coincidence and absorption methods.

Low energy beta ray spectra: Pm^{147}, S^{35}. H. C. PRICE, JR., J. MOTZ and L. M. LANGER,[1] Indiana University.—The beta spectra of S^{35} and ${}_{61}Pm^{147}$ have been measured in an attempt to study further the nature of the low energy deviation from the Fermi theory previously reported.[2, 3] Measurements were made with thinner sources and improved techniques in both the 40. cm radius of curvature spectrometer and also in a small 180 degree focussing Helmholtz coil spectrometer designed specifically for low energy spectra. The excess of particles at low energies was found to be a function of source thickness. The thinnest sources used were less than 10 micrograms/cm^2. Both S^{35} which is allowed and Pm^{147} which is probably once forbidden were found to have spectra of the allowed shape. Using counter windows of 3 micrograms/cm^2 and also a windowless counter technique, Fermi plots were obtained which, for Pm^{147}, were straight down to 8. kev. The end point of Pm^{147} was found to be 223.2 ± 0.5 kev. On the basis of an improved calibration of the instrument, the present results for S^{35} yield an end point of 167.0 ± 0.5 kev.

The disintegration energy of Al^{29}. L. SEIDLITZ, E. BLEULER, and D. J. TENDAM, Purdue University.—Shell structure models of the nucleus as proposed by Wigner[1], Feenberg and Hammack[2] and Nordheim[3], provide for no shell closures between Ne^{20} and Ca^{40}. The measured mass difference between Al^{28} and Si^{28}, however, is higher than expected from calculations based upon the above hypothesis indicating an especially stable structure for Si^{28}. A strong spin-orbit coupling, as proposed by Haxel, Jensen and Suess[4] and Mayer[5], could lead to a closed shell at Z (or N) $= 14$. If the $Al^{28} - Si^{28}$ anomaly is due to such a closure, then a similar result might be expected for the transition Al^{29}—Si^{29}.

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[1] Assisted by a grant from the Frederick Gardner Cottrell Fund of the Research Corp. and by the joint program of the ONR and AEC.

[2] C. S. Cook, L. M. Langer and H. C. Price Jr., Phys. Rev. **74**, 548 (1948).

[3] H. D. Albert and C. S. Wu, Phys. Rev. **74**, 847 (1948).

Al^{29} was produced by bombarding Mg with the α-particles of the Purdue cyclotron. The half-life was found to be $6.56 \pm .06$ m. Absorption and coincidence measurements show a complex β-spectrum of two components, each decay leading to an excited state of the residual nucleus. The two β-components have upper limits of $2.5 \pm .1$ MeV (70%) and $1.4 \pm .2$ MeV (30%) while coupled γ-rays have energies of $1.25 \pm .20$ MeV and $2.35 \pm .10$ MeV respectively. The total disintegration energy of $3.75 \pm .25$ MeV is approximately 1.7 MeV too high when compared with neighboring nuclei of the same symmetry (Ne^{23} 4.3, Na^{25} 3.7, Mg^{27} 2.64, Al^{29} 3.75, Si^{31} 1.8, P^{33}, S^{35} 0.167 MeV). This appears to confirm the evidence for a highly stable structure for Si^{28}.

On the design of iris-loaded waveguides. LEO M. SILBER, Purdue University.—The microwave linear electron accelerator utilizes a waveguide which will propagate a wave with a component of the electric field intensity in the direction of propagation, and a phase velocity less than the velocity of light. Ordinary waveguide is unsuitable because the phase velocity is greater than that of light. However, a circular waveguide loaded with circular irises can be designed to have the required properties. The present work is connected with the design of a standing-wave linear accelerator. An empirical relation was found between the geometry of the waveguide and the phase velocity of the wave. Using this relation an accelerator was designed to accelerate electrons from 300 KV to 1.2 MeV, or from a phase velocity of 0.77 c to 0.95 c. The experimental results have also been compared to the theory of electromagnetic waves in iris-loaded waveguides.

An experiment on the arrival angle of 3.2 cm microwaves. C. M. ZIEMAN, Wabash College.—To measure small variations in the arrival angle of microwaves, caused by changes in the vertical structure of the atmosphere, a transmitter, radiating at a frequency of 9520 megacycles, was placed on the observatory grounds at Mt. Wilson, California.

The radiated energy was focused by a metallic lens located at the California Institute of Technology about 7.2 miles away.

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[1] E. Wigner, *Physical Review*, **51**, 947, (1937).

[2] E. Feenberg and K. C. Hammack, *Physical Review*, **75**, 1877 (1949).

[3] L. W. Nordheim, *Physical Review*, **75**, 1894, (1949).

[4] O. Haxel, J. H. D. Jensen and H. E. Suess, *Physical Review*, **75**, 1766 (1949).

[5] M. G. Mayer, *Physical Review*, **75**, 1969, (1949).

The shift of the diffraction pattern, as measured in the focal plane of the lens, was taken as a measure of change in arrival angle.

Variations of the order of one tenth of a degree were noted. Such variations seem larger than can be accounted for by calculations based on ray theory.

Preliminary Theory of an Electrical Computer for Mean Deviations

RONALD L. IVES, Indiana University

Abstract

Computation of mean deviations can be expedited by use of an electrical device, in which mean values are attained by paralleling condensers upon which the initial value is proportional to the initial datum; and deviations are arrayed in correct arithmetical sign for subsequent meaning by use of diode bridge rectifiers. Standard electrical components, available for all major functions, permit relatively easy construction and maintenance.

Introduction

The laborious nature of the computation of a mean deviation, either "by hand," or on standard office computing machines, has inhibited the employment of this indicative statistic in many types of climatic work, as well as in other fields of investigation.

Because this computation, as normally performed, requires the rehandling of each primary datum, chances for arithmetical error are rather great. Repeated changes of operational procedure, during the computation of a single mean deviation, are confusing to all but the most skilled and alert computers, so that, even with a standard computing machine, errors tend to be numerous, requiring extensive recomputations, and raising the cost of the computation.

Within the last two decades, a part of the labor and proneness to error has been removed from this computation by the use of punch-card machines, notably those developed by International Business Machines Corp. By use of such machines, rehandling of a datum consists only of replacing the card in the machine, and, if the card is correctly punched initially, "transfer error" is virtually eliminated.

Despite this very real improvement, however, the computation of mean deviations remains a problem, for which an electrical computer offers a possible solution. This electrical computer, as here outlined, is about midway in complexity between a standard adding machine and the Bell Laboratories' relay computer. Because all fallible components are used in an "all or nothing" capacity, and are so connected that they either function or do not function, the problem of tube failure, so serious in some of the modern electrical computers, is minimized. By judicious use of suitable test problems, trouble, when it occurs, can be localized in a matter of a few seconds; and by employment of "plug in" units, trouble, when detected, can be corrected in a matter of a few minutes, usually as simply as a burned-out lamp bulb is replaced.

Mathematical Processes

To determine a mean deviation, as the process is normally performed, the following steps are necessary:

1. Sum the initial data.
2. Divide this sum by the number of items summed. This is the arithmetical mean.
3. Determine the absolute value of the difference between the arithmetic mean and each individual datum. These differences are the absolute individual deviations.
4. Sum the absolute individual deviations.
5. Divide the sum of the absolute individual deviations by the number of deviations summed. The result is the mean deviation.

This operational breakdown shows plainly the relatively large number of operations involved in the computation of a mean deviation. As the number of errors increases at a rate approximating the square of the number of items (figures) concerned, it is obvious that an operational simplification is much to be desired.

Formulas commonly used in computation of a mean deviation are presented in Fig. 1.

FORMULAE

Individual values $= X$

Number of values $= N$

$(\Sigma =$ "the sum of"$)$

$$\text{Arithmetic mean} = \overline{X} = \frac{\Sigma(X)}{N}$$

$$\text{Individual deviations} = x = |X - \overline{X}| = \left|X - \frac{\Sigma(X)}{N}\right|$$

$$\text{Mean deviation} = MD = \frac{\Sigma|x|}{N} = \frac{\Sigma|X - \overline{X}|}{N} = \frac{\Sigma\left|X - \frac{\Sigma(X)}{N}\right|}{N}$$

$$\text{Variability index} = \frac{MD}{\overline{X}} = \frac{\Sigma\left|X - \frac{\Sigma(X)}{N}\right|}{\Sigma(X)}$$

Fig. 1. Formulae used in computing mean deviation by conventional methods.

ELECTRICAL MEANING

Introduction

Determination of mean value can be made without adding and then dividing by a number of mechanical, hydrostatic, and electrical devices, most of which are both inordinately bulky and quite slow in operation. Several electrical devices, however, show definite promise, in that they are small, inexpensive, not prone to variation, and "instantaneous" in their operation. The best of these devices is a condenser bank, which performs automatically, in microseconds, a mathematical process requiring from several seconds to several days by more familiar methods.

Fundamental Theory

A condenser is an electrical storage device, consisting of two plates separated by a dielectric. When the potential difference (volts) between the plates of a condenser of known capacity (farads) is also known, the energy stored (coulombs) is shown by the formula:

$$Q = CE \text{ or } E = \frac{Q}{C}$$

In which:

Q = charge on condenser (coulombs)

C = capacity of condenser (farads)

E = potential across condenser (volts).

When several condensers, charged to voltages E_1, E_2, $E_3 \dots E_n$, respectively, are connected in parallel, their capacities add directly, and the total charge is the sum of the individual charges, or:

$$\Sigma C = C_1 + C_2 + C_3 \qquad C_n$$

and:

$$\Sigma Q = Q_1 + Q_2 + Q_3 \qquad Q_n = C_1E_1 + C_2E_2 + C_3E_3 \qquad C_nE_n$$

Now, as $E = \frac{Q}{C}$, the resultant voltage, E_r, across the condenser bank, is:

$$\frac{\Sigma Q}{\Sigma C} = \frac{C_1E_1 + C_2E_2 + C_3E_3 \qquad C_nE_n}{C_1 + C_2 + C_3 . \quad . \quad . \quad . \quad C_n}$$

and, if all capacities are the same (and all equal to C_1), then:

$$Er = \frac{C_1 \left(E_1 + E_2 + E_3 \qquad E_n\right)}{NC_1} = \frac{\Sigma E}{N}$$

which is the mean of the individual voltages. Additional details and fuller derivations may be found in any standard physics text, such as Smith (3).

Thus, by charging a group of identical condensers to voltages proportional to the various items, and then connecting the condensers in parallel, the mean of the various items may be determined from the voltage across the condenser bank.

Practical Application

One method of "putting this theory to work" is shown in Fig. 2. Here, the meaning device consists of a voltage source, a group of identical condensers, and a voltage measuring device.

In operation, the condensers are charged, one by one, from the voltage source, the applied voltage being proportional to the numerical datum concerned. When all condensers have been charged (or eliminated from the circuit by means of disconnectors—D_1, D_2, D_3 $\quad D_{n-1}$), they are all connected in parallel, by closing of the meaning switch, and the voltage across the condenser bank is measured ("drainless" V.T.V.M.). This voltage is the arithmetical mean of the initial charging voltages.

When the meaning switch is opened, all condensers have and retain the same voltage, which is the arithmetical mean voltage determined

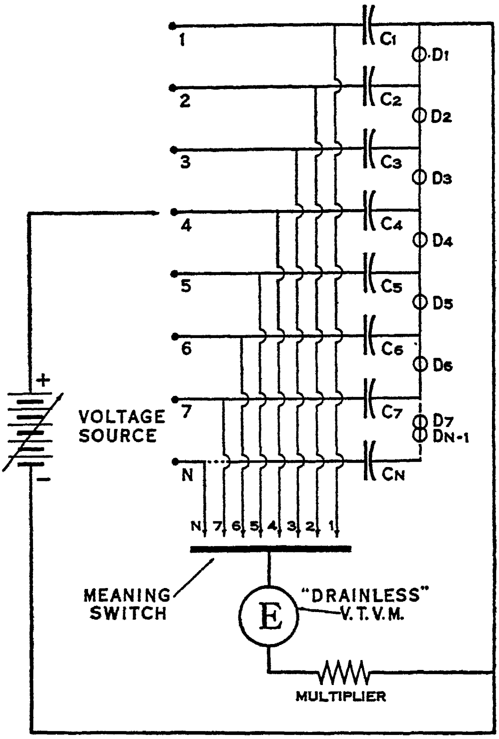

Fig. 2. Summary diagram of an electrical device for determining a mean value.

above. The meaning process is used twice in determining mean deviation: once to determine mean value, as outlined above; and a second time, with different components, to determine the mean value of the individual deviations.

ELECTRICAL MEMORY

Introduction

Determination of mean deviations requires that the individual data be compared with the mean of those same data, and that the absolute value of the difference, if any, be isolated and retained for further arithmetical treatment.

Various electrical and electromechanical devices can be made to retain a position, charge, or type of oscillation. Among those in common use are a ratchet-type stepping switch, a simple condenser, and a crystal-controlled mercury tank.

The simplest possible electrical memory—a condenser—is most suitable for use in this device.

Fundamental Theory

If two identical condensers are charged to a voltage proportional to each datum; and only one of these is connected into the meaning circuit, the other meanwhile being electrically isolated; the charge on the first, or meaning, condenser, after the meaning operation, will be the mean of all the data concerned; while the charge on the second condenser will remain unchanged.

Practical Applications

One method of retaining a charge electrically, or "remembering" a datum, is shown in Fig. 3, in which two identical condensers are charged simultaneously from each charging position. One of these condensers, Cm, is subsequently connected into the meaning circuit: the other, Ch, not so connected, is the "memory" element.

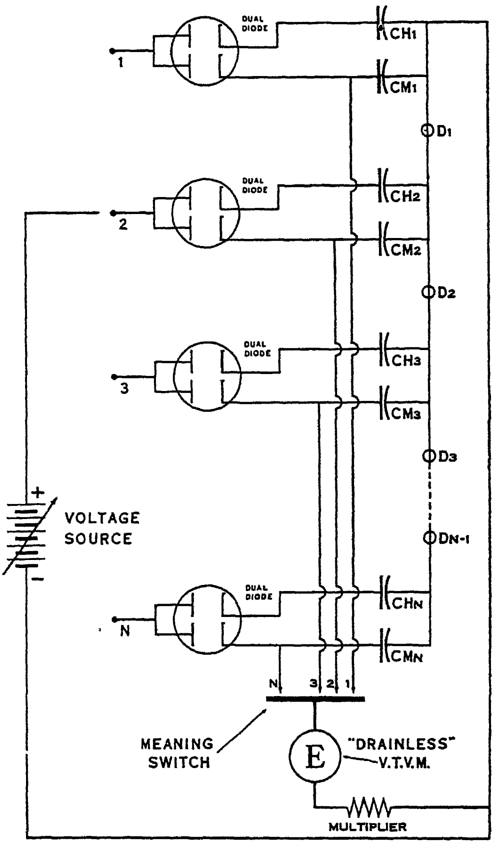

Fig. 3. Summary diagram showing one method of "memorizing" a datum while at the same time finding the mean value of a group of data.

Charging of both condensers in each pair is accomplished through a dual diode, which functions as an electrical check valve, to prevent circuit interaction. Were it not that the diode has an additional function, to be outlined later, the same operation could be performed more economically by a dual contactor on the charging switch.

DETERMINATION OF DEVIATION

Introduction

At this stage in the description, electrical methods of determining the mean value have been outlined, as well as a means of "remembering" the original individual data. After the meaning switch of Fig. 3 has been closed and reopened, the voltage across all the condensers designated Cm will be the same, and will be the arithmetical mean of the values to which they were initially charged. Voltages across the condensers designated Ch remain the voltages to which they were initially charged. The difference between these voltages is the deviation in each case, but, as some of the individual items are larger than the mean, and others are smaller, the absolute value of this difference, which is the desired figure, must be determined.

Because arithmetical sign of the difference between the mean value and the individual value is shown by the electrical polarity of the charge between the outer terminals (left-diode cathodes—Fig. 3) of the two condensers in each pair, determination of the mean of the absolute values of these differences, which numerically equivalent to the individual deviations from the mean, requires that they all be arranged in the same polarity, regardless of the polarity of the difference charge share by Cm and Ch.

Fundamental Theory

When two identical charged condensers are connected "back to back" (i. e. negative terminals together) as in Fig. 3 (Cm_1 and Ch_1, for example), the voltage across the free terminals (left, Fig. 3) will be the difference between their terminal voltages, with the polarity positive at the terminal of the condenser charged to the highest value.

In ordinary machine computation, the absolute value of the deviation is determined by the operator, who subtracts the lesser value from the greater in each case, so that the result is always positive. It is, of course, possible to perform a similar process electrically, by means of a polarized relay, for example. A simpler means, however, is to transfer a portion of this charge, representing the deviation, to another condenser, of known capacity, by use of a conventional bridge rectifier (1, p. 549 or 4, 479-480) which automatically polarizes the transferred charge.

When two charged condensers are connected in series opposition, or "back to back", the charge available for transfer is the difference between the charges, and, if the condensers are of like capacity, the charge is $C(E_1-E_2)$. When this capacitative pair is connected to a third condenser, by means of a bridge circuit, the condenser having the numerically greater charge will discharge into the third condenser, through the rectifier, until the terminal voltages on both sides of the rectifier are equal, or:—

$$C_1(E_1-E_2)-C_3E_3=C_3E_3$$

and, as the charge divides according to the capacities of the condensers:—

$$C_3E_3=\frac{C_1(E_1-E_2)}{C_1+C_3}$$

and:—

$$E_3=\frac{C_1(E_1-E_2)}{C_3(C_1+C_3)}$$

This permits a rather wide range of condenser values. If, for convenience in construction and computation, $C_1=C_3$, then:—

$$E_3=\frac{E_1-E_2}{2}$$

Practical Application

One of several workable methods of isolating a charge corresponding to each individual deviation from the mean value, of arraying these deviations in correct polarity, and of preserving the charges for following operations, is shown in Fig. 4. Here, the individual condensers having been charged, and the meaning process performed, all of the condensers designated Cm are charged to the mean value, which has been measured and recorded (if desired), and the holding condensers, designated Ch, retain the charges representing the original individual data.

When the switch arms connected to the deviation condensers, designated Cd, are moved from "center" to "down" position, the bridge rectifier circuits are completed, so that a known portion of the charge difference between condensers Cm and Ch is transferred to Cd. Although this transfer is theoretically instantaneous, it actually requires a few microseconds, because the diode circuit is resistive.

When the switch arms are again centered, charges on the individual deviation condensers (Cd) are proportional to the individual deviations from the mean value, the exact proportion being a function of the various capacities involved, as previously outlined.

Meaning of Deviations

Mean deviation is determined in the same manner as mean value, but is found by connecting all of the deviation condensers in parallel, and then measuring the voltage across the bank. This process is performed by moving all of the switch arms connected to the deviation condensers (Cd) to "up" position, and then measuring the voltage across the bank by means of the "drainless" V.T.V.M. By use of a second instrument multiplier ("Multiplier 2", Fig. 4), the mean deviation, as indicated

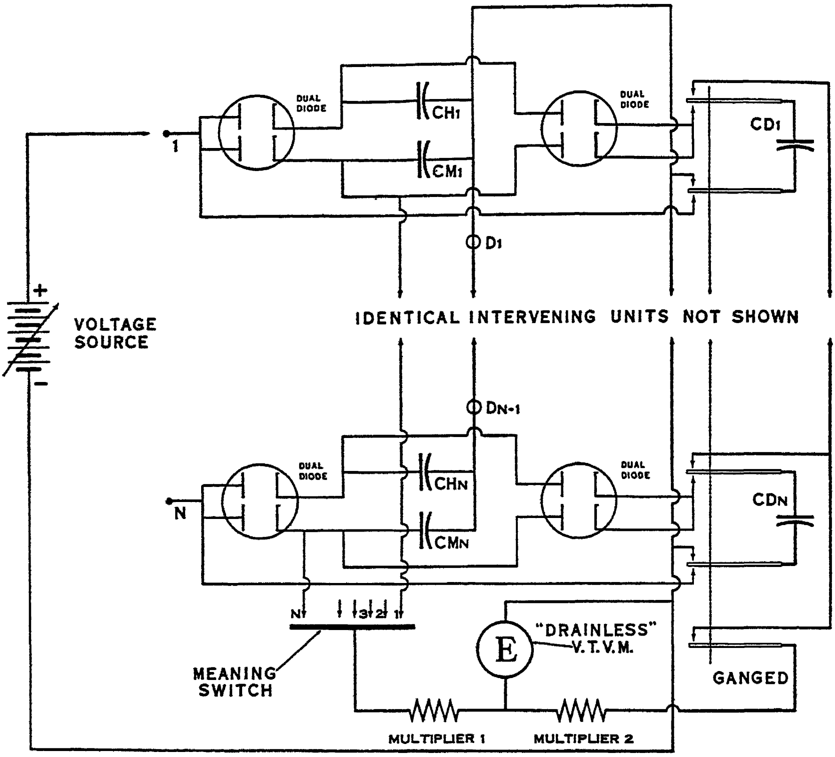

Fig. 4. Circuit for transferring deviation charges from mean and holding condensers to deviation condensers.

by the instrument, can be in the same terms as the mean value previously determined, thereby eliminating an additional computation (multiplication of the measured mean deviation voltage by a constant factor).

Clearing of Machine

After a computation is completed, it is necessary to clear the machine before a new sequence is started. This process is analogous to erasing a blackboard, and is done by "dumping" all of the charges residual upon the various condensers. Most convenient method of doing this is to short-circuit all of the condensers, which can be done, with the circuit of Fig. 4, by grounding the common of the meaning switch to battery—for the condensers Cm; commoning and grounding the upper cathodes of the left diodes for the condensers Ch; and, with the switch arms in "up" position, connecting switch arm at "multiplier 2" to battery— for the condensers Cd.

Several other charge dumping methods are possible. Choice of the exact method is unimportant, and depends largely upon the type of switching mechanism used.

Voltage Supply

Sources of potential for this computer, and for others of similar design, must be very stable, and not subject to either slow drift, or "poltergeist" variations in output potential. At the time of this writing (spring, 1949), several supplies having an output of 250 volts, with an accuracy of plus or minus one millivolt, are available (2, p. 258). Greater accuracy is attainable, but is quite costly at the time of this writing. The simplest way of converting output of a stabilized supply into the various voltages needed to represent individual data is by use of a decade voltage divider connection, which is ideally suited for key-punch operation.

Voltage Measurement

Measurement of the voltage across the condenser banks after the various meaning processes is best performed by use of a vacuum tube voltmeter, which can be designed to remove an entirely negligible portion of the charge during the measuring process. Various commercial types, of high accuracy, are available; some being designed to make a printed record of the measurements, on familiar "adding machine tape".

With some instruments, the power supply for the V.T.V.M. can be taken from the charging supply in such a manner that long-term voltage drifts are "cancelled out". When this is done, the exact output voltage of the supply need no longer be known, and the inserted and measured charges will be in approximate volts, rather than in standard volts.

It is also possible, by means of a vacuum tube bridge device, to determine the voltage across the condenser bank in terms of the supply voltage (or any known fraction of it); and several printing voltage comparators, of high accuracy and dependability, are now (1949) commercially available.

Adjunct Equipment

Various other items of equipment called for by the theoretical design here presented are all available commercially. The condensers can be standard low-leakage elements. Some now available have a loss of less than 0.1 percent of charge per hour, at full rating. As the time required for a single mean deviation computation is usually less than two seconds per unit, losses due to condenser leakage are negligible in most work.

Switching equipment of phenomenal dependability has been made for the communications industry for several decades, and is ideally suited for use in computing mechanism. Stepping switches and similar devices of this manufacture will commonly operate from 100,000 to more than 5,000,000 times without a failure. This equipment is very costly, compared to the items which perform similar functions in pinball machines and juke boxes, but, on a per operation basis, it is quite inexpensive.

Rectifiers used in the bridge circuit are standard dual diodes, of which the 6H6 is a familiar example. These have a nominal life of about 1,000 hours; and an actual life, in some instances, of more than 30,000 hours.

Economic Factors

A device of this general type, designed with 32 positions and an accuracy of five significant figures, such as is needed for meteorological and climatic computations, costs somewhere between $5,000 and $10,000, initially. Maintenance cost per operation, at least theoretically, is about the same as for a standard mechanical computing machine. Operator time required for computing each mean deviation is, or can be made, about one third that required for standard methods, and chances for operator error are about quartered.

In consequence, construction of a device of this type will be worth considering only when a very large number of computations must be made each year; or where speed of computation is essential.

Although use of "plug-in" units expedites repairs and maintenance, an electrical computer is usually not very satisfactory in locations where a competent maintainer is not available. Thus, although this electrical computer will theoretically expedite the computation of mean deviations, its construction is inadvisable unless and until it can be used on a full time basis in some location where dependable maintenance (and unfailing power supply) is available.

Summary and Conclusions

The foregoing theoretical outline shows that many troublesome computations can be expedited by use of electrical computing mechanisms. Determination of arithmetical means, and of mean deviations, can be performed electrically by straightforward application of well-known principles, employing standard mass-produced components.

Economically, however, use of electrical computers, even though they shorten work time and reduce chances of error, will probably and should be restricted to large computing centers, where the machines are operated nearly full time, and where adequate stable power supplies and skilled maintenance are available at all times.

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PSYCHOLOGY

Chairman: E. J. ASHER, Purdue University

R. W. Bruce, Wabash College, was elected chairman for 1950.

ABSTRACTS

Two Components of a Social Attitude. EMANUEL K. BELLER, Indiana University.—*Problem:* Sherif has stated that social attitudes are interiorized social norms. A modification is here suggested: One can distinguish two verbalizable components of a social attitude: (1) The interiorized norm (an internal response), which reflects a source that impels the individual to react in a positive, negative, or neutral way toward the relevant value object, (2) a behavioral disposition, which reflects other sources of instigation (including incompatible interiorized norms) and which is more likely to be in accordance with actual overt responses of the individual to the same value object.

Population and Procedure: A test was conducted to measure two components of the attitude toward prejudiced conduct in boys. These were the interiorized norms of and the behavioral disposition toward prejudice against Negroes. The test was given to thirteen groups (totaling 513 boys), in which age (9, 12, 15) and environment (institutionalized and non-institutionalized) were the independent variables.

These groups were compared with respect to their (1) verbalized behavioral disposition, (2) verbalized interiorized norm, (3) discrepancies between interiorized norm and behavioral disposition, and (4) degree of interiorization of norms of prejudiced conduct.

Results and Conclusions:

Comparisons between these groups showed that:

1. The measures of the two components yielded essentially different results for the 9 and 12 year old groups but not for the 15 year olds.
2. Behavioral Disposition. Prejudice increased with age in the non-institutionalized groups of boys. This trend was reversed in the institutionalized groups (the older boys were less prejudiced).
3. Interiorized Norms: Prejudice decreased from 9 to 12- and increased from 12 to 15 year old non-institutionalized boys. No trend with increasing age was found in institutionalized boys.
4. Interiorization of Prejudice: The 9 year old boys were more prejudiced in their 'interiorized norms' than in their "behavioral disposition". This relationship was completely reversed in the 12 year old boys. The difference of the relative position of the two components of prejudice disappeared in the 15 year old boys. (The orphan boys deviated from all the other subjects.)

Some further conditions of transfer of training. ROBERT W. BRUCE, Wabash College.—This is a further study of some of the conditions of transfer of training. We seek to answer these questions: What is the relation of the following conditions of learning to transfer: (1) Learning to make *successive* new responses to an old stimulus? (ab, ac, ad, ae, af); (2) Learning to make an old response to *successive* new stimuli? (ba, ca, da, ea, fa); (3) Learning to make *successive* new responses to *successive* new stimuli? (ab, cd, ef, gh, ij).

In general, the experimenters Hunter, Pearce, Wylie, Bair, Kline, and Bruce have found that (1) learning to make an old response to a new stimulus results in a marked degree of positive transfer; that (2) learning to make a new response to a new stimulus results in a slight degree of positive transfer; and that (3) learning to make a new response to an old stimulus results in very little transfer at all.

We have sought to extend this finding,—to carry these sequences further. Also, we offer a theoretical explanation for the phenomena disclosed.

We found that learning to make the *same* response to *successive* new stimuli, Condition II, results in such marked positive transfer (100, 56, 45, 36, 30) as to suggest, that the type of learning involved, in reality shifts from a retained members type of learning, to a recognition type of learning.

The considerable degree of positive transfer which occurs in learning to make successive new responses to successive new stimuli, Condition III, (100, 95, 89, 84, 80) suggests that successive learning as such, typically gives a small to fair degree of positive transfer.

The negligible degree of positive transfer which occurs in learning to make successive new responses to an old stimulus, Condition I, (100, 97, 97, 95, 95), suggests that the mere experience of learning these syllables undoubtedly aids, as is shown in the condition II results. On the other hand, a negative factor is undoubtedly present here, which more or less neutralizes the total final effect. In fact, several investigators including Kline have reported a very slight degree of negative transfer in the learning involved in making new responses to an old stimulus.

Two interpretations of concept formation. ARNOLD H. BUSS, Indiana University.—An experiment on concept formation was performed in order to compare the effectiveness with which two interpretations would handle the data. In traditional terms the purpose of the experiment was to study concept formation as a function of the proportion of positive and negative instances in the learning series. In learning terms the purpose was to discover the functional relationship between the tendency to make a particular response to stimuli with certain properties and the number of reinforcements of the response in the presence of these stimuli. The stimuli were blocks which varied in height, color and surface area; the top and bottom surfaces were triangular. There were five learning series, each having a different proportion of tall blocks (positive instances) and short blocks (negative instances). The subjects, 100 college students of both sexes, were divided into five groups of 20 each. Each group had one of the five learning series followed by a criterion series which was the same for all groups. The blocks were presented singly for five seconds, and the subject released one of two telegraph keys to indicate his choice. The subject was told "Right" or "Wrong" after each response in the learning series but not in the criterion series. The number "correct" and the frequency of responses were recorded.

The results indicated that the number "correct" is primarily a function of the kind of blocks in the criterion series rather than the proportion of positive and negative instances in the learning series. The frequency measures were found to be functionally related to (1) reinforcement of a particular response in the presence of tall blocks; and (2) nonreinforcement of this response in the presence of stimuli other than tall blocks.

Analysis of the Problem of Validation of the Rorschach Technique. B. D. COHEN, Indiana University.—Rorschach interpretation involves more complex behavior on the part of the psychologist than does the interpretation of more formally standardized test procedures for which precise tables of norms are available. With the Rorschach test, the individual interpreter is a more influential component of the instrumental procedure. Consequently, the problem of validation of the method is a particularly difficult one.

Clinical validation methods have established the Rorschach test as a working clinical instrument and have provided many provocative hypotheses. Many of these hypotheses can and should be subject to direct experimental verification procedures.

An analysis of the typical method whereby inferences are drawn from Rorschach data reveals a functional classification of validation procedures. Evaluation of these procedures indicates the most promising technique to be the prediction of behavior in specially constructed situations designed to test specific Rorschach hypotheses.

The interaction of responses to step function stimuli. DAVID CRAIG, Indiana University.—Research reported here was designed to provide information on the linearity of operator performance in a direct tracking situation by determining the extent to which the responses of the operator-apparatus combination to superimposed inputs conform to the responses of a linear system to such inputs.

Subjects tracked a spot which made step-function movements away from and back to a center position. Four different amplitudes of displacement were used. The time interval between members of each pair of opposed steps was varied so that both uncomplicated responses to single steps and overlapped responses were obtained.

Results indicate that the mean response of the operator-apparatus combination to a pair of opposed step inputs conforms to the requirements of a linear system for all amplitudes tested. However, the relationship between mean responses to single steps of different amplitudes does not fulfill the requirements of linearity. Information concerning the nature of this non-linearity will require further research.

The psychology of esthetics: a challenge. ROBERT E. DREHER, Wabash College.—It would be the writer's contention that the vast majority of studies catalogued under the classification of the psychology of esthetics might better be classified as the "psychology of esthetic elements"—*Tonpsychologie*, the psychology of line, color, et cetera. It has been safer (and easier) to continue in the Fechnerian tradition of esthetics "from below", apparently, than to attempt analyses of behavior to whole esthetic objects in an esthetic milieu. Some of the fairly obvious reasons for this state of affairs are considered.

It has been only in relatively recent years that psychologists have approached esthetic objects as proper stimuli for behavioral events with the same methods, techniques, and principles which have characterized "objective" psychology in other areas of experimentation. While the number of experimental studies which have been executed with this orientation to the psychology of esthetics is limited, several are cited to illustrate the efficacy of this "new" approach.

Progress in this field, we believe, depends upon the ingenuity and skill of future experimenters to devise more adequate techniques for the control and observation of esthetic behaviors as complex behaviors and to reject the atomistic and piecemeal approach which has dominated the orientation of workers in this type of research.

A preliminary report on the effects of glutamic acid on test scores. P. R. FULLER, D. G. ELLSON, and R. URMSTON, Indiana University.—In order to supplement previous experiments on the effect of glutamic acid on the psychometric test scores of mental defectives, an experiment of nine months' duration was performed at the Muscatatuck State School for the mentally retarded by members of the Indiana University Psychology Department. Thirty pairs of subjects, ranging in age from eight to seventeen years and in Stanford-Binet IQ from sixteen to seventy-four, were matched on the basis of age and IQ. The experimental group received glutamic acid in doses which were increased gradually from 4 to 30 grams per day; the control group received a placebo.

Five tests, the 1937 revision of the Stanford-Binet, the Cornell-Coxe, a rate of tapping test, a digit span test, and a coordination test in which both time and errors were recorded, were administered just before the experiment began. After 4½ months and after 9 months the tests were again administered. The testers did not know which subjects were receiving glutamic acid and which ones were receiving the placebo.

The experimental (glutamic acid) group made a greater increase in Stanford-Binet IQ and in the rate of tapping than did the control (placebo) group. On the other hand, the mean Cornell-Coxe score and digit span of the control group increased more than did those of the experimental group. None of these four differences was statistically significant. However, the control group showed significantly greater decrease in errors on the coordination test while the experimental group showed a greater decrease in the time required to perform the coordination test.

In this experiment, supranormal amounts of glutamic acid were not shown to result in significant improvement in psychometric test scores.

The effect of a verbal stimulus as a reinforcement. JOEL GREENSPOON, Indiana University.—The purpose of this research was to determine the effect of a verbal reinforcement introduced immediately following a plural noun response on the frequency of plural noun responses. Twelve college students were randomly assigned to the experimental and control groups. The experiment was conducted in a soundproof room and was recorded on a wire recorder. A chronoscope was used to record the time.

The subjects were instructed to say all the words that they could think of, but were not to use sentences, phrases, or to count. In the case of the experimental group, immediately after each plural noun response the verbal reinforcement, "Mmm-hmm", was introduced by the experimenter. No reinforcement was introduced for the control group. The subjects responded for a period of twenty-five minutes. At the end of the experimental session each subject was asked if he knew what had been transpiring in order to determine if he could verbalize any changes that may have occurred in his behavior.

The results were computed on the basis of five minute periods. The percentage of plural noun responses to the total number of responses was computed for each period and for the total experimental session. It was found that the experimental group gave a significantly larger number of plural nouns than the control group. None of the experimental subjects was able to verbalize any changes in his behavior.

It can be concluded that "Mmm-hmm" is a reinforcement in this type of training and changes in verbal behavior can occur without the subjects' being able to verbalize them.

Indirect extinction of a conditioned response. NORMAN GUTTMAN and WILLIAM K. ESTES, Indiana University.—Can a conditioned instrumental response be extinguished without actual elicitation? We have attempted to answer this question by analyzing the sequence of movements comprising a bar-pressing habit into its component S-R correlations and then eliminating the final member of the sequence before beginning experimental extinction.

Two groups of four albino rats were first conditioned to press a bar for water reinforcement in a Skinner-type apparatus. After both groups had received 500 reinforcements, the experimental group was given six daily 30-minute periods of "indirect extinction." During these periods, the bars were removed from the apparatus. The animal was free to move about in the box during the entire period, and at intervals of about 90 seconds was stimulated by operation of the empty magazine. At first all animals approached the magazine whenever the motor sounded, but during the six periods this behavior extinguished. Finally, both groups were given experimental extinction of the bar-pressing response. During a 30-minute period, the animal was confined in the apparatus with the bar available but disconnected from the magazine. All bar-pressing responses were recorded.

Extinction curves for the bar-pressing response revealed marked differences in form. The experimental group started at a higher rate, but extinguished much more rapidly. The higher initial rate is presumably due to the previous separate extinction of the final component of the response, which reduces the minimum time required for execution of a response. The more rapid extinction may be attributed to the elimination of secondary reinforcement.

In summary, it appears that a conditioned instrumental response may be weakened, but not completely extinguished, by separate extinction of its final component.

An application of the operant conditioning paradigm to human studies. E. J. HOVORKA, Indiana University.—*Purpose:* (A) To measure stimulus generalization. (B) To test the applicability of the operant conditioning procedure to human studies.

Population: 62 students of elementary psychology.

Procedure: After an initial test on 12 mathematical problems, each subject was placed in a semi-darkened room and told that he would be re-tested in an hour and could play with a machine in the room if he wished.

Three neon lights, mounted on the machine flickered at a rate determined by the experimenter. If the subject pressed a foot-pedal on the machine, a cartoon illuminated by a 30 watt light dropped into view for twelve seconds. In this situation, the cartoon is specified as the reinforcing stimulus for the pedal-pressing response.

Each subject was allowed to present himself in this manner with 16 cartoons while the neon lights flickered at a rate of 2 flashes per second. Following the 16th reinforcement, subjects were distributed among seven extinction groups. The difference between the seven groups was the rate of flicker of the neon lights which assumed one of the values; ¼, ½, 1, 2, 4, 8, or 16 flashes per second. Under these conditions no further reinforcements were available and extinction curves were collected.

Results and Conclusions: The length of time and number of responses made to a criterion of 15 minutes of no responding were computed for each of the 7 groups. Although a double-winged stimulus generalization gradient is suggested, the differences between groups are not statistically significant. The mean extinction curve presented closely resembles the extinction curves produced by pigeons and rats in comparable situations.

A follow-up analysis of an apprentice selection program. E. J. McCormick, and J. B. Moretti, Purdue University.—The purpose of this investigation was to ascertain the relative effectiveness of a battery of tests that had previously been used in the selection of apprentice applicants for a training program in the car and locomotive repair shop of an operating railroad.

In the original testing 83 applicants were given the following tests:

1. Purdue Adaptability Test
2. Purdue Mechanical Adaptability Test
3. Purdue Industrial Mathematics Test
4. Industrial Training Classification Test
5. Can You Read a Working Drawing?

Thirty-six of these subjects were selected for training. 13 of this group were separated for various reasons, leaving the group of 23 trainees. Results of this study are based upon 19 trainees.

Intercorrelations between test scores and three criteria were computed. The Wherry-Doolittle Test Selection Method was worked against each of the three criteria with the following results:

1. School performance. The Purdue Mechanical Adaptability Test, the Industrial Training Classification, the Adaptability Test and Can You Read a Working Drawing? were found to give the optimum predictability of school performance, with a shrunken multiple correlation of .643. The Adaptability Test and Can You Read a Working Drawing? entered into this prediction with negative weights; while they gave the "symptoms" of operating as "suppression" tests to the other two, it is probable that such results were due to chance factors such as the small number of cases.

2. Shop performance. The Purdue Mechanical Adaptability Test was found by itself to give the optimum degree predictability of shop performance.

3. Criterion of combined performance. The Purdue Mechanical Adaptability Test and Can You Read a Working Drawing? were found to result in the optimum degree of predictability of combined school and shop performance, with a shrunken multiple correlation of .610. While Can You Read a Working Drawing? entered into this prediction with a negative weight, and appeared to operate as a "suppression" test, it is probable that such results were due to chance factors.

Eye reaction as an indicator of emotion. Robert Stanley Ort, Wabash College.—A research study in the field of experimental psychology on the validity of involuntary eye movement as an indicator of emotion. Thirty-two female subjects were given a word association test consisting of 5 presumably non-loaded words and 5 presumably loaded words, during which time their eye-movements were being recorded by an American Optical Company Opthalmograph. The response, reaction-time, and any other visible indicators of emotion such as a laugh were recorded.

The number of eye reactions were then compared with the number of other complex indicators for the presumably non-loaded words. The same procedure was followed for the presumably loaded words. The words were then listed in the order of presentation, and the number of times each word elicited one or more of the known complex indicators was recorded. In addition the number of times each word was accompanied by eye reaction, was recorded.

The results show that a greater number of words are accompanied by eye-reaction, in either the non-loaded or the loaded words, than by all other indicators combined. The words indicated to be loaded, by any one or more of the known indicators, were found to be accompanied by eye-reaction in 79.74% of the cases. It appears that involuntary eye-movement is a more sensitive indicator of emotion than any of the customarily used complex indicators.

The relationship between an individual's role in a homogenous group and his awareness of that role. HOMER G. WOOD, Purdue University.—A sociometric questionnaire covering nine social areas was administered to a fraternity group consisting of thirty-four members, all of whom had lived at the fraternity house for a period of at least one year prior to the administration of the test. Each member of the group was asked to name those individuals in the house with whom he would most like to participate in each of the nine functions, and, also, to name those individuals with whom he would least like to participate. In addition, each man was asked to name those individuals in the house whom he thought would either choose or reject him in any of the categories. An analysis was made of the relationship between the number of sociometric votes, choice or rejection, received by an individual and his ability to estimate which individuals had actually chosen or rejected him.

ZOOLOGY

Chairman: M. R. Garner, Earlham College

S. Crowell, Indiana University, was elected chairman for 1950.

ABSTRACTS

Lateral loop chromosomes and the theory of the gene. Edward O. Dodson, University of Notre Dame.—Because of the facts of position effect, many geneticists have proposed modifications of the gene theory, with Goldschmidt proposing that the theory of the corpuscular gene must be abandoned, and substituting for it the theory that the chromosome is a continuum in which overlapping segments of varying lengths are the functional units. Observations on the lateral loop chromosomes of amphibian oocytes suggest that segments of the chromosomes far larger than estimated sizes for genes do function as a unit in the synthesis of lateral loops and nucleoli. While these facts do not prove Goldschmidt's theory, they are more easily interpreted in terms of it than they are in terms of the theory of the corpuscular gene.

The problems of making ecological observations in a tropical rain forest. Clarence J. Goodnight, Purdue University.—During this past summer an attempt was made to investigate the ecology of a tropical rain forest near Palenque, Chiapas. Studies were made of the soil fauna and of the various layers of the area. These studies indicated that the fauna of the tropical area had a greater variety of species than temperate areas; but without numerous individuals of any one species. Since the whole area presented equally good habitats, it was difficult to find any particular concentration of species.

The comparative toxicity of chloral hydrate and chloral alcoholate. Phillip V. Hammond, Donald E. Stullken and William A. Hiestand, Purdue University.—According to popular belief the mixing of chloral hydrate with an alcoholic beverage results in the formation of chloral alcoholate, a substance supposedly having greater hypnotic property than the hydrate, the mixture being popularly known as a "Mickey Finn". Chloral hydrate is used clinically as a somnifacient and anticonvulsant and to a greater degree in veterinary medicine as a narcotic. For this reason a comparative study of the toxicities of the two substances based on their LD_{50} values was undertaken.

Wistar rats and mice of the Hygienic and Swiss strains were used in the non-fasted state. Both sexes were employed and the animals standardized as much as possible by controlling weight, diet, and housing conditions. All animals that survived the trial dosage were discarded and not used again to prevent any cumulative effect of the substances. The mice received injections subcutaneously while the rats were injected intraperitoneally. All dosages were computed on accurate weights of the animals.

In terms of grams per kilogram dosage in both rats and mice the toxicity of chloral hydrate proved greater than that of chloral alcoholate. The LD_{50} of chloral hydrate for rats by intraperitoneal injection was 0.628 g. per kilo; of chloral alcoholate 0.756 g. per kilo. The LD_{50} of chloral hydrate for mice by subcutaneous injection was 0.909 g. per kilo; of chloral alcoholate 0.945 g. per kilo.

Thus the hydrate is more toxic than the alcoholate.

Reactions of two closely related species of salamanders to certain environmental factors: A study in comparative behavior. C. P. HICKMAN and F. JOHN VERNBERG, DePauw University and Purdue University.[1]—In order to understand better a few of the environmental factors that determine an animal's choice of habitat, reactions to certain gradients were studied and compared in two species of salamanders, *Plethodon glutinosus glutinosus* and *Plethodon cinereus cinereus*. These factors were: reactions to light; reactions to soil-moisture gradient; reactions to hydrogen-ion concentration of soil, and the oxygen consumption of the two species.

Eight gradients of white light and colored light were used for their light reactions. Results showed that both salamanders were negatively phototropic. An increased intensity of white light excited *P. g. glutinosus* more than *P. c. cinereus*. Red and green lights stimulated *P. c. cinereus* more than blue light; in contrast blue light stimulated *P. g. glutinosus* more than the other two. *P. c. cinereus* avoided green light more than red or white light of one foot-candle. *P. g. glutinosus* preferred soil with a higher moisture content than did *P. c. cinereus*. Both species avoided soil of pH 5.8 but chose soil having a pH range from 6.2 to 7.2. The oxygen consumption of *P. g. glutinosus*, averaging 5.33 grams in weight, was 124.29 cubic millimeters of oxygen per gram per hour. *P. C. cinereus*, averaging .73 grams, consumed 149.92 cubic millimeters of oxygen per gram per hour. Results indicate that *P. c. cinereus* was the more active form.

Evaluation of criteria used for generic separation of North American freshwater Tetraonchinae. BENEDICT J. JASKOSKI.—Nine genera of North American Tetraonchinae which were proposed by Mueller[2] were reduced to three in number by Mizelle and Hughes[1] on the basis of insufficient morphological differences considered necessary for generic distinction. Since the discovery of additional species which possess the principal character for each of the old genera *Pterocleidus* and *Haploclidus*, it is thought timely to reconsider these as natural groups which may warrant subgeneric standing. *Haplocleidus* which was based principally on a discrepancy in size of the haptoral anchors, was found invalid by Seamster[2] since *Cleidodiscus pricei* belonging to a different genus was found to possess size variations in the anchors, equivalent to those in *Haplocleidus* species. This presently invalid genus if used as a subgenus should be redescribed on a morphological basis rather than on a size difference of structures.

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[1] Work completed at DePauw University.

[2] Mueller, Justus F. 1934. Parasites of Oneida Lake fishes. Part 4. Additional notes on parasites of Oneida Lake fishes, including descriptions of new species. Roosevelt Wild Life Annals **3**:335-464.

————. 1936. Studies on North American Gyrodactyloidea. Trans. Amer. Micros. Soc. **55**:335-373.

————. 1937. Further studies on North American Gyrodactyloidea. Amer. Midl. Nat. 18:207-219.

Ecological observations on the helminths of some Wyoming voles (*Microtus* spp.). MERLE L. KUNS, Purdue University.—During the summer of 1948, eleven species of helminths were recovered from one hundred and three voles collected in the Jackson Hole region of Wyoming. Two parasites are reported for the first time from North America, viz., *Hymenolepis horrida* (Linstow, 1900) and *Heligmosomum costellatum* (Dujardin, 1845) and one of nematodes, *Nematospiroides sp.*, is apparently new.

In the Jackson Hole area, six rather well-defined habitats were studied. These ranged from the dry sage flats of the valley floor to the sub-alpine meadows at 11,000 feet altitude. A direct relationship between host density and incidences of infection is evident from the data obtained. No indications of host preference were noted for the parasites studied.

Only two parasites were generally distributed: these were *Paranoplocephala infrequens* and *Syphacia obvelata*, which occurred in all habitats except the sage flats. The trematode, *Quinqueserialis hassalli*, was limited to wet meadows at low altitudes, presumably because of the localized distribution of its molluscan intermediate host. One cestode and three nematode species were recovered only in highland habitats (above 9,200 feet altitude). Since an intermediate host is not known to be required for any of these species, an adequate explanation of their limited distribution is apparently lacking.

The effects of *Veratrum viride* on the blood sugar level of the albino rat. DAVID E. MANN, JR., ARTHUR G. ZUPKO, PHILLIP V. HAMMOND, WILLIAM T. ROCKHOLD and WILLIAM A. HIESTAND, Purdue University.—Veratrum viride acts as a cardiac depressant by stimulating the vagal centers of the medulla resulting in decreased pulse rate and blood pressure. Once used clinically to relieve hypertension, it has now been largely supplanted by drugs of lesser toxicity. Despite this fact, the pharmacology of V.v. is still being investigated.

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[1] Mizelle, John D. and R. Chester Hughes. 1938. The North American freshwater Tetraonchinae. Amer. Midl. Nat. **20**:341-353.

[2] Seamster, A. P. 1938. Studies on gill trematodes from Oklahoma fishes: Ibid. **20**:603-612.

The purpose of this experiment was to observe the effects, if any, of this drug on the blood sugar level of the albino rat. Twenty mature rats of both sexes were fasted for 12 hours prior to the withdrawal of blood from the tails. The 10 animals in Group I, ranging in weight from 169 to 340 grams, were injected intraperitoneally (immediately after the initial withdrawal) with a 0.1 mg/kg dose of a freshly prepared aqueous solution of V.v. (1 mg/cc). Twenty minutes after each injection, a second blood sample was obtained by decapitation. The 10 animals in Group 2 (247 to 390 grams) underwent the same procedure with the exception that they were injected ip. with an aqueous solution of V.v. that had been refrigerated for 3 days. Blood sugar determinations were made by the Folin-Wu micro method.

Freshly prepared aqueous solutions of V.v. caused hypoglycemia within 20 minutes in mature rats which had fasted for 12 hours. The average blood sugar decrease was 30.6mg%. Aqueous solutions of V.v. which had been refrigerated for 3 days caused hyperglycemia with an average blood sugar increase of 41.8mg%.

The use of monogenetic trematode parasites as an aid in the identification of fishes. JOHN D. MIZELLE.—Studies during the past ten years have shown that specificity between North American freshwater Tetraonchinae and their fish hosts is so marked in many cases that unmistakable identification of the host can be made on the basis of the parasites present. In several instances a single species of parasite occurs only on one species of fish. In other cases the same species of parasites may be common to two or more fish hosts but usually additional parasitic species occur, making taxonomic distinction clear. In several cases, notably in the Centrarchidae, differentiation between hosts cannot be made on the basis of Tetraonchinae present because the apparent host specificity is too broad, or the parasites harbored are too plastic to effect a taxonomic separation.

Experiments with muscle contraction. JOHN PAUL OVENS.—The purpose of the investigation was to determine the effect of various cations and anions on the irritability of a nerve muscle preparation. The preparations were immersed for thirty seconds in the solution to be tested and then arranged in the conventional manner of a nerve muscle preparation utilizing non-polarizable zinc electrodes. Solutions tested were distilled water, amphibian Ringer's solution, amphibian Ringer's with an excess of calcium, amphibian Ringer's with an excess of potassium, chlorides of sodium, potassium, calcium, barium, and magnesium, Anions tested were carbonate, sulfate, and phosphate. Two decalcifying acids, oxalic and citric, were also tested.

The intensity of the stimulation was governed by use of a dual range voltage divider and millivoltmeter.

The results of these experiments show that cations have a more marked effect on irritability than do the anions. With an excess of potassium or calcium in Ringer's solution there is a slight decrease in the irritability, but when these are present as chlorides the decrease is much greater.

Magnesium slightly decreased irritability but the effect was peculiar insofar as the break contractions persisted for 150 millivolts and then disappeared for 100 millivolts and later reappeared.

Sodium decreased the irritability but to a lesser extent than did potassium.

Barium had no drastic effect on irritability but did alter the nature of the contraction insofar as the rate of relaxation was slower while the circuit remained closed.

Oxalic acid greatly reduced the irritability of the preparations while citric acid inhibited any response whatsoever.

The effect of carbonate ions was similar to that obtained with sodium chloride. It was concluded that the carbonate ion had little or no effect on irritability and that the effects shown were due to the presence of the sodium cations.

Phosphate ions increased the irritability considerably.

Sulfate caused peculiar reactions but by comparing its results with those obtained with sodium chloride, its effect is one of decreasing irritability.

Ecological observations on the spring and winter rotifer populations of a pond in west central Indiana. FRANCIS A. PRAY, Purdue University.—A study was made of the spring and winter rotifer populations of a fresh water pond located near Purdue University, West Lafayette, Indiana. Collections and observations were made weekly over a sixteen week period, beginning January 8, and ending April 30.

At the same time that the rotifer collections were made, chemical and physical data were also recorded. Readings for air and water temperatures, dissolved oxygen, pH, and alkalinity were regularly taken.

The most important rotifers present under winter conditions were *Polyarthra platyptera* and *Conochiloides natans.* As spring conditions became established, the importance of these two species diminished and *Keratella sp.*, *Synchaeta pectinata,* and *Asplanchna brightwelli* became the predominate forms. The significant factor in the change from winter to spring fauna was observed to be a change to a greater number of individual species, rather than a great increase of total individuals of all species. A total of thirty-nine species and thirty-two genera was recorded during the investigation.

The metabolic effect of the administration of Thiouracil on *Periplaneta americana*. ROBERT A. REHM, DePauw University.—Since the appearance of thiouracil within the last few years, there has been a great deal published concerning its effect on the vertebrates; but a relatively small amount of work has been directed toward the invertebrates.

For this work the metabolic index employed was that of the carbon dioxide output as determined by a modification of Lund's (1919) method.

The experimental animals were fed a mixture of powdered bread and thiouracil, consisting of 150 grams of bread and 0.150 grams of thiouracil. In the period of twenty-one days the metabolic rate of the experimental animals had been inhibited by forty-four per cent.

An effective method of demonstrating longitudinal binary fission of Euglena. ARTHUR LOUIS SCHIPPER.—Microcultures of *Euglena* are made by: (1.) ringing a microscope slide with melted petroleum jelly, (2.) placing a small drop of *Euglena* culture in the center of the ring, and (3.) affixing a coverslip to the petroleum jelly in such a way that an effective seal is made. These microcultures are then exposed to artificial light for a period of approximately twelve hours prior to use. Subsequent examinations will reveal the presence of numerous fissioning euglenae. Best results are obtained if the microcultures are used within twenty-four hours after preparation. Since locomotion is extremely limited during fission, this process can be observed for its entirety without necessitating the movement of the microscope slide.

Polyvitelliny in *Stagnicola reflexa* (Say). ARTHUR LOUIS SCHIPPER.—The presence of two or more embryos in an egg has been reported for other Lymnaeid snails. This condition has been noted to be of frequent occurrence upon examination of egg clutches of *Stagnicola reflexa.* In most instances not more than one egg of a clutch will contain multiple embryos. Normal development and hatching occurs if not more than two embryos are present. If the egg contains numerous embryos development continues until the egg becomes completely filled. Under such conditions hatching has not been observed.

Birds of the Sierra de Palenque Foothills, Chiapas, Mexico. RICHARD E. TASHIAN, Purdue University.—During the summer of 1949, a section of northeastern Chiapas, Mexico, in the vicinity of the Mayan ruins of Palenque, was visited for the purpose of gathering ecological, distributional, and taxonomic data on the ornithology of that region. The area studied was situated in tropical rain forest located in the foothills of the Sierra de Palenque at an elevation of 210 meters.

Eighty species of birds representing 31 families were observed or collected. This constituted a resident population with the exception of two specimens of a Louisiana Waterthrush *(Seiurus motacilla)* collected on July 21 and Aug. 2, and one specimen of a Least Flycatcher *(Empidonax minimus)* collected Aug. 6. Nesting data were obtained on the Mexican Royal Flycatcher *(Onychorhynchus mexicanus)* and the Guatemalan Spotted-breasted Wren *(Thryothorus rutilus)*. There was evidence of breeding in 27 species, and molting was evident in 30 species. Twenty-three per cent of the species examined were found to be infected with helminth parasites in the following percentages: Cestoda, 44%; Nematoda, 36%; Trematoda, 12%; and Acanthacephala, 8%. To the recorded forms known from the Palenque region 36 were added of which 6 were new to the Gulf lowlands of southern Mexico, and two previously unrecorded from Chiapas.

Preneoplastic manifestations in mammalian thyroid glands. JOHN H. VAN DYKE, Indiana University School of Medicine.—During development an enigmatic epithelial structure (the ultimobranchial body), derived from the hind end of the embryonic pharynx, comes to lie within or near the center of each lateral lobe of the thyroid gland. Here, apparently, it becomes induced to transform into functional thyroid parenchyma (?).

However, in rats postnatal ultimobranchial tissue, which is normally indistinguishable from thyroid tissue, may be modified by feeding vitamin A deficient diet; or similarly altered by administration of estrogens or methylcholanthrene.

Following initial hyperplasia, this tissue usually transforms, through metaplasia, into multiple cysts lined by stratified squamous epithelium. The adjacent peripheral thyroid follicles undergo general atrophy. Normal old age rats frequently exhibit this metaplasia; often associated with spontaneous cystadenomata.

In rats the usual site of maximal mitoses appears to be in the center of each thyroid lobe, particularly during experimental hyperplasias. In yearling sheep, spontaneously activated thyroid glands containing ultimobranchial cysts exhibit little or no evidence of mitosis in general thyroid parenchyma. In contrast, however, there is a compensatory proliferation of masses of relatively undifferentiated cells from the bases of epithelial cysts of ultimobranchial tissue origin. These cells transform, presumably "on demand", into typical thyroid tissue in a manner to be described.

The evidence suggests that ultimobranchial tissue is plastic, normally indistinguishable from thyroid tissue, and may function after birth as a thyroid growth center, or, being labile, may undergo cyclic phenomena depending upon factors altering thyroid activity. Conditions augmenting thyroid hyperactivity in mammals (including man), particularly those with ultimobranchial lesions, may predispose individuals to certain compensatory neoplasms—especially during senility.

Plans for an experimental laboratory in the Biological Sciences now being conducted at the College of the University of Chicago. HOWARD H. VOGEL, JR., University of Chicago—During the past year a committee of the staff of the Biological Sciences in the College of the University of Chicago has been planning a laboratory for the general introductory course. This is a course in general education which has been offered for the past eighteen years, usually with an enrollment of 500 to 800 students. The course was largely organized by Dr. Merle Coulter who was its chairman until July, 1948 when he resigned to become Associate Dean of the Division of Biological Sciences in the University.

The course is well known for a series of excellent laboratory demonstrations, but because of physical limitations of space and equipment, it has never before tried individual laboratory sections. During this year of 1949-50 the laboratory program will be carried out on an experimental basis.

A laboratory section will consist of 24 students. The laboratory program will be divided into three quarters. During the fall quarter the *dynamics of protoplasm* will be the general heading. The students will be confronted with a problem: "What are the broadest attributes which characterize protoplasm as a living substance?" The laboratory work of the winter quarter will center around the *dynamics of the organism* and will draw mainly from the fields of physiology and psychology. The spring quarter will deal with the *dynamics of the species* and will consist largely of genetic and ecological studies.

Several unique characteristics of this laboratory program should be pointed out:

(1) The material is all presented in the form of broad general questions to the students. Problems are broken up into several sub-problems, each of which is studied by a separate committee of from two to six students.

(2) After each main problem the various sub-committees convene in the laboratory as a "committee of the whole" to discuss their results and integrate these to the main problems formulated. In this way we plan a good deal of discussion to go on concurrently with the experimental portion of the laboratory program.

(3) There is no credit at present given for this laboratory. The program is optional and is added to the student's course work. There are no grades given for the laboratory.

An investigation in the natural history of spiders. GERTRUDE L. WARD, Earlham College.—Spiders were collected and observed over a period of four months, at Ann Arbor, Mich. Temperature and activity of the spider at the time of capture were correlated. During captivity, records were kept on molting, feeding habits, building of nests, egg laying, and death.

The effect of methyl folic acid on the alkaline phosphatase of the oviduct of chicks. M. X. ZARROW, Purdue University.—Histochemical studies were carried out on the alkaline phosphatase content of the oviduct of folic acid deficient chicks. At 19 days of age the oviducts of the untreated birds showed a high concentration of alkaline phosphatase while the oviducts of the birds treated with the folic acid antagonist were markedly depleted of the enzyme. Injection of stilboestrol in normal chicks caused an increase in the weight of the oviduct and a high concentration of the enzyme was observed. However, the effect of stilboestrol on the oviduct of the folic acid deficient chick was markedly inhibited with regard to both increase in weight and amount of alkaline phosphatase.

The Effects of Pinealectomy on Young White Leghorn Cockerels[1]

C. J. SHELLABARGER and W. R. BRENEMAN

Introduction

The possibility that the pineal body is an endocrine gland has been a perplexing problem for many years. Pinealectomy has proved to be difficult, and previous investgators have been hampered by not obtaining enough operated animals to draw valid conclusions. Moreover, these investigators have reported results that are in conflict. Jullien (4) reported for example, that guinea pigs implanted with pineal substance have smaller gonads while Borrel and Ostrom (2) reported similar results when rats were pinealectomized.

Material and Methods

White Leghorn cockerels were used because they have a relatively fast growth and the maturation of the gonads occurs at relatively early age. The chicks were raised in battery brooders on the same food, and under the same light, heat, and space conditions. Each cage utilized contained equal numbers of the three groups of animals used in this study, i.e. control, sham operated, and operated.

Operations were performed at four days post-hatching in the following manner. The chicks were anesthetized with ether, placed under a binocular microscope, and a median incision 2 cm. long was made through the skin at the apex of the head. The fascia was removed by scraping with a sharp scapel and a incision was made at the fusion of the frontal and parietal bones, followed by a + incision through the dura. The last incision ruptured the dural sinus, and exposed the pineal body, which was then removed by means of fine jewelers forceps after which the edges of the skin were sewed together and gentian violet applied to prevent cannibalism. In addition to unoperated-controls sham operated-control animals were used and were handled in the same manner as those which were pinealectomized, with the exception that the pineal body was not removed.

The bodies, combs, and the endocrine glands were weighed at autopsy, and special care was taken with operated chicks to determine if the pineal body was completely removed. Chicks with a partial removal of the pineal body were discarded.

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[1] Contribution No. 413 from the Department of Zoology, Indiana University, and No. 99 from Waterman Institute, Indiana University.

Observations

No significant difference was found in the body weights, or in the weights of adrenals, thyroids, or the pituitaries. The comb weights of the pinealectomized chicks were found to be significantly larger than the comb weights of the two control groups, only at the age of 70 days.

The pinealectomized chicks, however, were found to have signficantly smaller testis weights than the controls at the age of 19 days. The testis weight, however, returned to normal at the age of 28 days and remained so until about 40 days. Shortly after the age of 40 days, the operated chicks were found to have significantly larger testis weights, but this increase was no longer evident at 94 days.

The operative mortality is summarized in table I and the testis weights are summarized in table II.

TABLE I. Operative Mortality

Series 1	totals	female	died from operation*	gland not removed	discarded	died	autopsied
Operated	55	3	10	8	2	2	30
Sham operated-controls	22	0	3	0	0	0	19
Control	18	1	0	0	1	1	15
Totals	95	4	13	8	3	3	64
Percentage	100.0	4.2	13.6	8.4	3.2	3.2	67.4
Series 2							
Operated	78	5	15	9	0	2	47
Sham operated-controls	60	1	11	0	2	3	43
Control	47	3	0	0	1	3	40
Totals	185	9	26	9	3	8	130
Percentage	100.0	5.0	14.0	5.0	1.6	4.4	70.0

* Chicks that died within 72 hours after operation were placed in this classification.

Discussion

When a significant statistical difference was found between the testis weights of the pinealectomized chicks and the controls, a signficant statistical difference could usually be demonstrated between the pinealectomized chicks and the sham controls. Also, the testis weights of the control chicks were never found to differ from the testis weights of the sham controls. Thus it is suggested that the effects on testis weights were due to the removal of the pineal body rather than the effects of the operation.

TABLE II. Testis Weights

Age in days	operated	sham operated-control	control	t-value
19	N 15	15	15	2.329*
	mean 28 mg	43	36	
28	N 11	9	9	
	mean 54 mg	51	52	
40	N 10	8	9	
	mean 88 mg	95	92	
42	N 15	9	5	2.104*
	mean 160 mg	133	115	
50	N 11	11	11	2.544*
	mean 155 mg	133	122	
70	N 10	5	5	2.177*
	mean 597 mg	288	382	
94	N 5	5	5	
	mean 5.8 gm	6.0	6.5	

* t-value computed on operated chicks compared to control chicks.

The weights of the testes of the operated chicks seemed to vary in two directions. First, the testis weights of the operated chicks were decreased at an early age (19 days). At the next age group autopsied (28 days) the weights of the testis of the pinealectomized chicks has returned to normal and remained normal until 42 days. Then an increase in testis weights of the operated chicks was noted, and increased testis weights remained above the weights of the testis of the control chicks until somewhere between 70 and 94 days. A corresponding increase in comb weights was noted at 70 days. These data might suggest that possible effects of pinealectomy should be looked for during the early part of the chick's life cycle.

It was mentioned earlier that a paradox seems to exist between the results of implantation and pinealectomy and these reports may be examined in the light of our observations on age differences in response to pinealectomy. Jullien implanted pineal substance into guinea pigs and stated that the gonads were smaller in the experimental animals, and on the other hand, Borell and Ostrom reported smaller gonads following pinealectomy of rats. Einhorn and Rowntree (3) reported that injection of pineal substance resulted in earlier breeding of successive generations of rats, but Martin and Davis (6) obtained earlier breeding in cats following pinealectomy.

Badertscher (1) reported the gonad weights of pinealectomized chicks to be unchanged. It is suggested by my data that somewhere after 70 days, in the chick, the pineal body has no effect on the testis, and Badertscher did not autopsy any chicks until the 228th day and thus his samples were autopsied at an age that would have been too old to detect any differences in testis weights.

Likewise, Kolzelka (5) reported that the implantation of pineal substances into cocks resulted in unchanged testis weights of the experimental animals. This might also be the result of the lateness of the implantation, as the chicks were half-grown, which would be beyond the 90 day limit suggested by my data.

Now, in an attempt to bring a small amount of order out of this seeming chaos, two assumptions must be made. Assumption one—the removal of the pineal body results in a dual effect on gonad weights. Assumption two—it would seem reasonable to expect that the removal of the pineal body would produce the opposite effect as the addition of pineal substance by injection or implantation. Since the time factor is important, if the pineal body were removed at an early age, a decrease of testis weights might be expected if the experimental animals were autopsied at an early age. If the pineal body substance were added by injection or implant at an early age, and the experimental animals were autopsied at a much later age, a decrease of testis weights might also be expected.

Thus it seems that both the technique of pinealectomy and the technique of implantation and injection should be re-explored during early growth periods, while maintaining a constant time factor. The conflict in reported results might eliminated in such a manner.

Summary

It is suggested that pinealectomy of four day old White Leghorn Cockerels has the dual effect of first decreasing the weights of the testes and later causing an increase in the weights of the testes.

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Indiana Academy of Science members in good standing are eligible to submit papers for publication in the Proceedings. When a paper is signed by two or several authors, all must be members in good standing. Preferably, eligibility should be established before submitting the paper, as such papers are given priority. In any case, all authors must be certified by the Treasurer for payment of dues and old reprint bills at the time of the deadline (see below). Papers reaching the editor after the deadline are ineligible. All papers must be accompanied by an abstract in the form specified below, marked "for the editor".

Abstracts

If the Divisional Chairman puts a paper on his program for the Fall Meeting, the abstract will be printed in the Proceedings regardless of the author's membership status, unless the full paper is published.

Time and procedure for Submitting Abstracts: One typed original of each abstract, marked "for the editor" may be submitted to the Divisional Chairman before the meeting or the author may mail it direct to the editor. This should be ready for publication with a minimum of editing, i.e., in the standard abstract form (see a Proceedings abstract) and double spaced; it should not include directions to the chairman regarding time, lantern, etc. The latter information may be added to a copy marked "for the Divisional Chairman" and sent to him. The editor cannot accept carbon copies of abstracts or papers. The length of an abstract should not exceed 200 words. Items No. 1, 2, 4, 5, 6, 14, and 15 apply generally to abstracts as well as papers.

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Whether sent *via* the Divisional Chairman as prescribed, or directly, all material for the Proceedings must reach the editor within 20 days following the Fall Meeting.

Preparation of Manuscripts

1. Refer to Volume 59 of the Proceedings for the accepted style of abstracts and papers, and follow this, especially in **literature citations,** headings, and footnotes.
2. Type on 11 x 8½ inch bond paper with a new ribbon, leaving ample margins. Double-space everything, including title, author's names and institutions, footnotes, quotations, legends and literature list. This original will become the printer's copy; if it must be retyped it will be sent back to the author for this.
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4. Literature citations should not occur in footnotes, but in an alphabetized list at the end of the paper headed "Literature Cited". The highly abbreviated form used in some publications has not been adopted for the Proceedings. If your abstract must cite literature, use foot notes for this.

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Selection of Papers

Every year a few more papers are submitted than can be published with **the available funds.** Therefore, not all papers received can be included in the Proceedings. Of those accepted, it is usually necessary that some be reduced in length by the authors, before publication. Manuscripts prepared concisely, in the style recommended above, will receive first consideration. Authors should not expect to publish very long papers in the Proceedings. Among papers of primarily regional interest, e.g., in certain aspects of botany, zoology, geology, geography, and anthropology, those dealing with Indiana material will be accorded preference.

The selection of papers for the Proceedings is the responsibility of the Editorial Committee.

INDEX

Acetyl transphosphorylase metal requirement, 37
Actinomyces scabies, 43
Adams, N. E., vi
Adams, W. R., 19
Adis-Castro, Elias, 17
Africa, 34
Agropyron repens, 75
Ahrendt, M. H., vi
Algae, 41, 44, 80
Allyn, W. P., vi
Aluminum, effect on potato scab, 43
Analytical Chemistry, Academic Training in, 131
Angel Site, 19, 25, 28
Antagonism, by *Streptomyces albus,* 71.
Anthropology, Section on, 17
Antibiotics, 38
Apprentices, Selection of, 289
Asher, E. J., v, 283
Atrypa, A new species of, 246
Auckerman, L. W., 266
Authors, Directions to, 303

Bacteria, of urinary infections, 38
Bacteriology, Section on, 37
Baldinger, Lawrence H., vi
Banta, Edna, vi
Barnes, W. B., vi
Barton, Thomas F., 216
Beal, Juna L., vi
Bechtel, A. R., v, vi, 40
Beckert, C. H., 212
Beckmann rearrangement of oximes of quinolylketones., 134
Beech, 82
Beghtel, Floyd, vi
Behrens, C. A., v, xi, xiv
Beller, Emanuel K., 283
Bennett, R. E., 37
Berg, Philip W., 157
Bessel functions, 264
Beta spectra, 266, 270
Bieber, C. L., 221
Birds of northeastern Chiapas, Mexico, 296
Blattella germanica L., 173
Bleuler, E., 270
Bloom, W. W., 53
Bohman, Frank E., 156
Botanists of Indiana and Pakistan, 47
Botany, Section on, 40
Breneman, W. R., 299
Brock, J. E., 267
Brodie, H. J., vi
Brown County, Ecology in, 45
Bruce, R. W., 283, 284
Brucella, 37
Bruner, J. A., 266
Bryophytes, Indiana, 112, 115
Buls, Erwin J., 225
Burr, I. W., 264
Buss, Arnold H., 284
Byren, E., Jr., vi

Calculus, History of, 265
Campaigne, E., 122
Caribs, Anthropology of, 17
Carnahan, Walter H., 264
Carpenter, I. W., Jr., 41
Carpenter, T. R., 40
Carr, Arthur B., 212
Chandler, Leland, 82
Chanin, M., vi
Chemistry, Section on, 122
Chemistry texts, 140
Chen, H. H., 126
Chiapas, Mexico, Birds, 296
Chloral alcoholate and chloral hydrate, comparative toxicity., 291
Chlorophyll therapy, 41
Christy, O. B., v, vi, xiv, xv
Chromosomes, Lateral loop, 291
Cleland, Ralph E., v, vi, 40
Coats, Nellie M., v, vi, x
Cohen, B. D., 285
Cohen, I. Roy, 37
Cole, L. C., vi
Concept formation, 284
Contributors, Instructions for, 303
Commerce of Ireland, 251
Computer for mean deviations, 273
Conditioned response, 287
Congo Culture Area, 34
Corley, R. C., vii, 123
Corn, 2, 4-D effects, 44
Corum, C. J., 38
Cottingham, John O., 58
Craig, David, 285
Crowell, S., 291
Cummins, George B., 40
Curry, Hilda J., 25

DDT toxicity, 157, 185
Daily, Fay Kenoyer, vi, 41
Daily, William A., v, x, xi
Damon, S. R., 37
Dannin, Albert G., 41
Davis, Delmar O., 267

Davis, J. J., v, vi
Deam, C. C., v, 48
Deay, Howard O., vi, 156
Deckard, Anne De Boer, 123
Degering, Ed. F., v, 126, 150
Dehl, Lamont, 213
Dehydrogenations by means of sulfur, 153
De Moss, R. D., 37
DenUyl, Daniel, vii, 59
Deuterons, 267
Deviations, mean, Computor for, 273
Devonian of Montana, A new species of *Atrypa* from the, 246
Dextrins, limit, utilization of in animal body, 123
Diphenylketene, 150
Dodson, Edward O., 291
Disintegration energy of Al^{29}, 270
Dreher, Robert E., 286
Driver, Harold E., 17
Drummond, Robert R., 213

Earth mover, 213
Ecology, Brown County, 45
Edington, Will E., v, vi, 1
Edwards, P. D , vi, vii, xiv
Electrical behavior of semi conductors, 268
Electron accelerator, linear 269
Elliott, F. R., vi
Elliott, S. E., vi, vii
Ellson, D. G., 286
Elving, Philip J., 129
Elzay, Richard, xx
Enders, H. E., v
Entomology, Section on, 156
Epistemic Correlation, The, 265
Ervin, Robert F., v
Esten, Mabel M., 41
Esten, S. R., vi
Estes, William K., 287
Esthetics, Psychology of, 286
Euglena, binary fisson in, 296
Euoenothera, 40
Everly, Ray F., 164
Evolution, in Plecoptera, 197
Eye reaction indicating emotion, 289

Fertility in *Agropyron repens,* 75
Fireblight, pear resistance to, 40
Fischer, Robert B., 131
Fishes, identification of, 294
Fission, *Euglena,* 296
Fluoboric acid, preparation, 144
Fluosilicic acid, reaction with boric acid, 144
Flutes, Bone, 28
Food Animals, Indian, 19
Folktales, African, 34
Fontaine, W. E., 267
Friesner, Ray C., v, vi, vii, x, 42, 48
Fuller, Harry J., xiii
Fuller, P. R., 286
Fungi of Marion County, Indiana, 58
Gantz, E. S., v, vii
Garner, M. R., v, 291
Gay, Kathleen, 37
Gene theory, 291
Genzer, Jerome D., 134
Geographic Recreational Aspects of Unglaciated Indiana, 216
Geology and Geography, Section on, 212
German Roach, 173
Gibbium psylloides, Biology of, 156
Gingery, W. G., vi
Glacial drift, 214
Glow discharge, influenced by irradiation, 269
Glutamic Acid, 286
Goodnight, Clarence J., 291
Goodspeed, James C., 134
Gopalkrishnan, K. S., 42
Gould, G. E., 173
Grand Portage Fur Traders Route, 225
Grassi, Gino V., 43
Grave, Benjamin H., 1
Greenspoon, J., 287
Gries, George A., 43
Ground-water levels in Indiana, 236
Group, Individuals role in, 290
Growth-rainfall trend coefficients, 42
Guard, Arthur T., vii
Guennel, G. K., 43
Guernsey, James L., 230
Gunsalus, I. C., 37
Guttman, Norman, 287

Haas, H. B., 150
Hall effect, 269
Hammond, Phillip V., 291, 293
Hanske, Carl F., 1
Hare, Robert R., 264
Hargitt, Thomas F , 3
Harned, R. L., 38
Hartsell, S. E., 38
Hartzler, H. Harold, 267
Hass, H. B., 150
Heiser, Charles B., 64
Heller, Z. H., 267
Helminths, parasitic in voles, 293
Hennion, G. F., vi
Herbicides, 44
Hickman, C. P., 292
Hidy, P. H., 38
Hiestand, William A., 291, 293
Hoshaw, Robert W., 44
Hovorka, E. J., 288
Howell, L. B., vi
Hung, C. S., 268
Huyck Preserve, Algae of, 80

Hyatt, J. L., vi
Hydrogen detector, electronic, 266

Illinoian Tillplain, Secondary succession on, 95
India, Botanists of, 47
Indiana plant distribution records, 48
Insect control, Ultrasonics in, 156
Insecticides, toxicity of DDT isomers and analogues, 157
Insecticide tests, 173
Insects of peaches, 181
Insects, toxicity of DDT, 157
Interference fringes, 267
Iodine, orthatolidine method for determining, 155
Iodine trichloride, 122
Ireland, Commerce of, 251
Isopropenyl acetate, acetylation with, 126
Ives, R. L., 273

James, Hubert M., 268
Jaskoski, Benedict J., 292
Johnson, W. H., v, vi, xi
Johnson, V. A., 269
Jones, K. L., 38
Jump, J. A., 71
Junior Academy of Science, vi, x, xix, xx
Just, Theodor, v

Karling, John S., vi
Karst valley in western Monroe County, 258
Kaslow, C. E., 134
Keesom, P. H., 268
Kessel, W. G., v, 122, 140
Ketene, 150
Ketones, Quinolyl, 134
Kingsbury, T. M., 213
Kintner, Edward, v, vi, 156
Klaer, Fred H., Jr., 236
Klopp, George D., 4
Koch, G. David, 213
Koffler, Henry, 37
Korevaar, T., 265
Kottlowski, Frank E., 246
Kuns, M. L., 293

Laboratory, experimental, Plans for, 297
La Croix, J. Donald, 44
Lake Chicago, glacial, Forests of, 43
Langer, L. M., 266, 270
Lark-Horovitz, K., 268, 269
Lead coated iron, 144
Leckrone, Walter, vi
Lefforge, J. H, 75
Lefler, R. W., vi, x
Legume pollination, 164
Leonard, G. W., Jr., 144
Leuconostoc acetyl transphosphoylase, 37
Lilly, Eli, v, vii
Limestone, rapid analysis of, 149
Limnology, 295
Lindsey, A., v, vi
Liriodendron, 41
Liver glycogen of rat after administration of limit dextrins, 123
Liverworts, Indiana, 112
Loew, Fred A., vi
Long, Alma, vi
Lost River, 214
Lysozyme, the microbiological determination of, 38

McBurney, Marion J., 38
McClure, S. M., 147
McCormick, E. J., 289
McCoy, Scott, vi
McGrain, Preston, v, 212, 214
MacKay, John W., 269
McQueeney, Carl R., 45
Machard, H. H., v
Mackell, J. F., v
Mahin, E. G., v, vi
Malott, Clyde A., v, 214
Mann, David E., 293
Maple, Sugar, 46
Mapping, Topographic, 212
Markle, M. S., v, vi, 40, 80
Marling, J. A., vi
Marshall, G. E., 181
Martin, R. Earl, vi
Mathematics, Section on, 264
Mathematics, European, 265
Mathers, F. C., 144
Mean Deviations, Electrical Computer for, 273
Means, K. S., v, vi, vii
Median, Distribution of, from a certain general population, 264
Meissner, K. W., 267, 269
Mellon, M. G., xiii, xiv
Members, new, 1949, xvi
Methyl folic acid, effect on chick oviduct, 298
Meyer, A. H., vi
Michaud, H. H., v, vi, x, xxiii, xxiv
Microscope stages, Centering of rotating, 129
Microwaves, 271
Miller, Chester W., 46
Miller, Maurice M., 270
Minutes, Executive Committee, viii
Minutes, General session, xiii
Mizelle, John D., 294
Moffat, D., 266
Monogenetic trematodes, 294
Monroe County, Karst valley in, 258

Moon, Tom, xx
Moretti, J. B., 289
Morgan, Will P., v, vi, viii
Moss, Melvin J., 129
Motz, J., 270
Mullett, R. P., 185
Muscle contraction, 294
Musical instruments, archaeological, 28
Mycologist, responsibilities of, 8

Necrology Memorials, 1
Nematocide screening, 156
Neumann, George K., 17
New Members, xvi
Niemann, Lois Jean, 265
Nitrogen Tetroxide, 150
Noyes, Bessie, vi
Nuclear shell structure, 270
Numerical systems, Analysis of, 18

Oenothera taxonomy, 40
Ohio River formation, 215
Oil, Secondary recovery of, 213
Operant conditioning, 288
Orthotolidine method for determining iodine, 155
Ort, Robert S., 289
Outwash patterns, 221
Ovens, John Paul, 294
Overman, Paul, 264

Painting, negative, 25
Palmer, C. M., xiii, 47
Patton, John B., 215
Payne, F., v, vi
Peach Insects, 181
Pear, fireblight in, 40
Pearson Type III distribution, sampling from a, 265
Periplaneta americana, 295
Personnel selection, 289
Phaseolus, root-stem transition, 43
Phillips, F. J., 149
Phosphate, pebble, 212
Physics, Section on, 266
Physoderma graminis, 42
Pierson, R. M., 269
Pinealectomy in cockerels, 299
Pits, sand and gravel, 221
Plant distribution records, 48
Plecoptera, Evolutionary trends in, 197
Pollen analysis, Bog, 43
Polley, J. Crawford, vi, 265
Pollination, legume, 164
Polyploidy, 64
Polypodium spp., 102
Polyvitelliny, 296
Porter, Charles L., v, vi, viii, 8
Porter County pteridophytes, 53
Posey County, 17
Potato scab, Effect of aluminum ions, 43
Potzger, Esther, 95
Potzger, J. E., vi, 82, 95
Pray, Francis A., 295
Presidential address, 8
Price, H. C., 270
Pseudococcus maritimus, 210
Psychology, Section on, 283
Pteridophytes, 53

Railway pattern, Canadian, 215
Rall, Waldo, 270
Ramsey, R. R., v
Rasp, notched, 17
Recreational Aspects, Unglaciated Indiana, 216
Reed, H. J., vii
Reflection echelon, shape of fringes, 267
Regeneration in planted conifers, 59
Rehm, Robert A., 295
Remmers, H. H., vi
Reynolds, A. E., vi
Rhynsburger, Willert, 215
Ricker, W. E., v, vi, ix, 197
Riel, F. J., 150
Ripley County, Beech in the forests of Laughery Creek, 82
Rockhold, William T., 293
Roller, D., xiii, 266
Rorschach technique, 285
Rosenthal, Arthur, 265
Rothrock, David A., 5
Rotifer populations, 295
Rubber, Crystallization of, 268
Rusts, *Stipa*-mallow, 40

Salamanders, Study of, 292
Salzmann, Zdenek, 18
Sand and gravel pits, 221
Sand, character of, 215
Sand, High-silica, 215
Schaeffer, H. F., 153
Schipper, Arthur Louis, 296
Schuder, D. L., 210
Schweinsberger, Sanchia, 28
Science Talent Search, vi, x
Scintillation counter, 270
Scott, Richard A., 102
Seidlitz, L., 270
Semi-conductors, 267, 268
Seybert, J. E., vi
Seymour, Keith, 122
Shellabarger, C. J., 299
Shepherdson, W., vi
Silber, Leo M., 271
Single Subject System in chemistry, 147
Smith, Howard W., 156

Smolelis, A. N., 38
Snail, fresh water, 296
Social Attitude, 283
Spiders' natural history, 298
Stagnicola reflexa, 296
Starkey, O. P., 212
Star, photoelectric light curve of, 268
Steels, stress-rupture, 267
Step Function Stimuli, Responses to, 285
Stimulus generalization, 288
Stipa-mallow rusts, 40
Stoneman, E. A., 251
Streptomyces albus, antagonism by, 71
Streptomycete, antibiotic, 71
Strickler, A., vi
Stullken, Donald E., 291
Succession, in an abandoned field, 95
Sulfur, dehydrogenations by means of, 153
Swallow holes, 214, 258
Switzer, J. E., v, vi

Tapscott, Marjorie, xx
Tarson, Samuel, 267
Tashian, R. E., 296
Taxus Mealybug, Control of, 210
Tendam, D. J., 267, 270
Terre Haute, Trade area, 230
Testing, Personnel, 289
Tetraonchinae, Generic separation of, 292
Thiouracil, 295
Thomas, A. R., v, 266
Thompson, R. L., 38
Thompson, Wayne, 122
Thrun, W. E., 155
Thunderstorms of Indiana, 255
Thyroid gland, 297
Tolypella prolifera Leonh., 41
Trematode parasites, 294
Tropical rain forest ecology, 291

2, 4-D, Butyl ester of, 44
2, 4-D effects on corn, 44
Unglaciated Indiana, 216
Urmston, R., 286

Vaccinia virus, 38
Valparaiso Moraine, Pteridophytes of, 53
Van Dyke, John H., 297
Veratrum viride, effects of on blood sugar of albino rat, 293
Verbal reinforcement, 287
Vernberg, F. John, 292
Visher, Stephen S., v, vii, 255
Vitamin B_{12} Assay, 37
Vogel, Howard H., Jr., vi, 297
Voles, helminth parasites of, 293

Wabash drainage basin, 214
Wade, F. B., v, vi
Wagner, K. A., 112
Wallace, F. N., v, vi, vii, x
Wallace, William, v
Ward, Gertrude L., 298
Warren, C. P., 34
Water well records, 213, 236
Waveguides, iris-loaded, 271
Wayne, William J., 258
Weatherwax, Paul, v, vi, vii
Weeds, 64
Welch, Winona H., v, vi, 115
Whitaker, P. L., vi
Wilkin, Marian L., 38
Wood, Homer G., 290
Wright, J. S., v, vi, vii, viii

Youse, Howard Ray, vii
Yunker, T. G., v, vi, ix, 48

Zarrow, M. X., 298
Zieman, C. M., 271
Zoology, Section on, 291
Zupko, Arthur G., 293

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